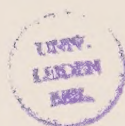


HEALING AFTER TREATMENT OF PERIODONTAL INTRAOSSEOUS DEFECTS

STEFAN RENVERT

Malmö 1984

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1984*



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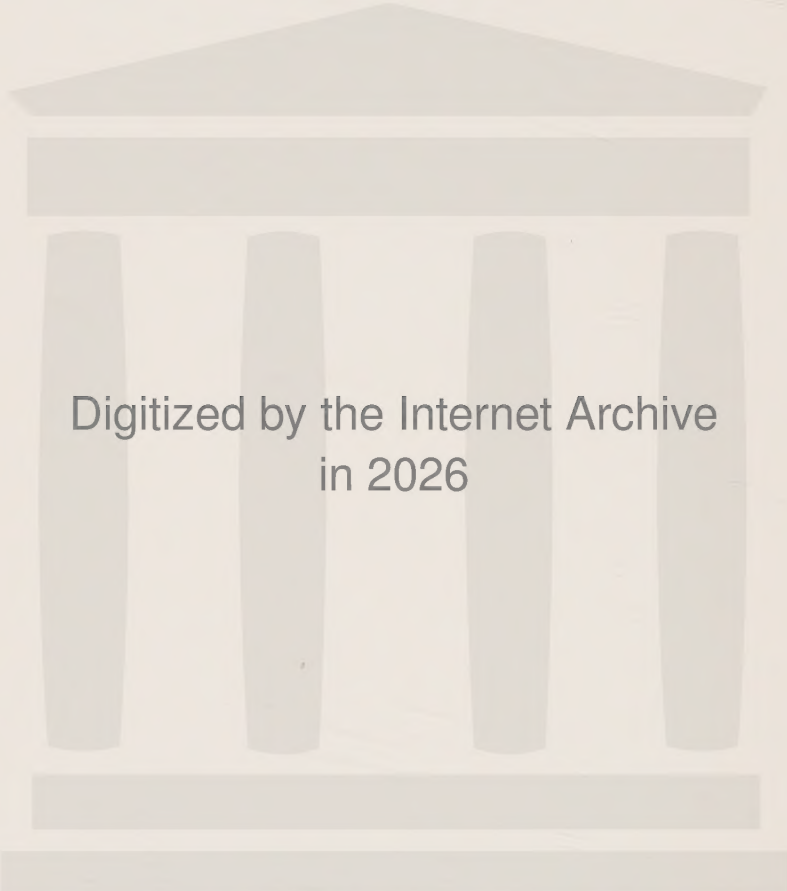
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PREFACE

This thesis is based on the following papers, which will be referred to by their Roman numerals.

- I. Renvert, S., Badersten, A., Nilvéus, R. & Egelberg, J. (1981) Healing after treatment of periodontal intraosseous defects. I. Comparative study of clinical methods. Journal of Clinical Periodontology 8, 387-399.
- II. Renvert, S. & Egelberg, J. (1981) Healing after treatment of periodontal intraosseous defects. II. Effect of citric acid conditioning of the root surface. Journal of Clinical Periodontology 8, 459-473.
- III. Renvert, S., Garrett, S., Schallhorn, R.G. & Egelberg, J. (1984) Healing after treatment of periodontal intraosseous defects. III. Effect of osseous grafting and citric acid conditioning. Journal of Clinical Periodontology. Submitted for publication.
- IV. Chamberlain, A.D.H., Garrett, S., Renvert, S. & Egelberg, J. (1984) Healing after treatment of periodontal intraosseous defects. IV. Effect of a non-resective versus a partially resective approach. Journal of Clinical Periodontology. Submitted for publication.
- V. Renvert, S., Nilvéus, R. & Egelberg, J. (1984) Healing after treatment of periodontal intraosseous defects. V. Effect of root planing versus flap surgery. Journal of Clinical Periodontology. Submitted for publication.
- VI. Renvert, S., Garrett, S., Nilvéus, R., Chamberlain, A.D.H. & Egelberg, J. (1984) Healing after treatment of periodontal intraosseous defects. VI. Factors influencing the healing response. Journal of Clinical Periodontology. Submitted for publication.

INTRODUCTION

Resorption of alveolar bone as a result of destructive periodontitis may be localized to a single tooth or tooth surface. A localized periodontal pocket associated with bone destruction apical to the level of the surrounding alveolar crest is referred to as an intraosseous lesion. Intraosseous defects have been classified according to the number of osseous walls circumscribing the lesion into 1-, 2- and 3-wall defects. The number of osseous walls adjacent to the defect has been considered to influence the therapy of choice (Goldman & Cohen 1958).

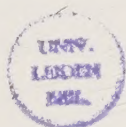
SURGICAL PROCEDURES

The presence of bony walls around the intraosseous lesion is thought to favor regeneration of periodontal tissues following therapy. Therefore, most of the surgical procedures that have been developed over the years are regenerative in nature.

Full coverage flap surgery: This surgical intervention includes a sulcular or reversed bevel incision followed by reflection of mucoperiosteal flaps. Pocket epithelium and granulomatous tissues are removed. The root surfaces are debrided and planed. The flaps are replaced at original level or positioned apically and sutured in order to obtain full coverage over the surgical wound (Ellegaard & Löe 1971, Polson & Heijl 1978, Rosling et al. 1976b).

Denudation procedure: For this technique, the free gingiva overlying the lesion is removed followed by reflection of full thickness flaps. Granulomatous tissue is removed in order to expose the intraosseous defect. After debridement the flaps are sutured at the level of the alveolar bone crest leaving the orifice of the osseous defect uncovered by soft tissue. The defect orifice is covered by tinfoil or Telfa[®] and by periodontal dressing (Prichard 1957, 1983).

Osseous resection: Full coverage and denudation procedures can be performed with or without concomitant osseous resection. Resection of bone is performed in order to reduce or eliminate the bony defect and to improve



the osseous tissue topography (Schluger 1949). A distinction between osteotomy and osteoplasty has been done. Osteotomy involves removal of tooth supporting bone, whilst osteoplasty refers to reshaping of non-supporting alveolar bone (Friedman 1955).

Grafting procedures: In order to enhance the regeneration potential in periodontal intraosseous defects various materials have been grafted into the defects.

Osseous autografts: Intraoral sources for osseous graft material are the maxillary tuberosities, healing extraction sockets and edentulous ridges. For cancellous bone and marrow grafts the cortical bone is removed before the graft is placed in the defect. For the osseous coagulum or bone blend techniques particles of both cortical and cancellous bone are grafted (Robinson 1969, Diem et al. 1972).

The iliac crest has served as an extraoral source for autografts. This graft material has been transplanted directly, after refrigeration before usage, or cryogenically frozen (Schallhorn et al. 1970).

Osseous allografts: Iliac allografts (Hiatt & Schallhorn 1971) and freeze-dried bone allografts (Mellonig et al. 1976) have the advantage of being available without the requirement of a separate surgical procedure to retrieve the graft material.

Demineralized dentin: Freshly extracted, vital human roots are freed of periodontal ligament, cementum and pulp tissue. The remaining dentin is cut into small pieces, demineralized, lyophilized and sterilized before implantation (Movin & Borring-Møller 1982).

Ceramics: Grafts of specially prepared and commercially available hydroxyapatite have been used as implants in intraosseous defects (Rabalais et al. 1981, Froum et al. 1982a).

Xenografts: Other graft materials that have been used include bovine osseous tissues (Older 1967, Nielsen et al. 1981).

EVALUATION OF HEALING RESPONSE

Clinical methods: In clinical studies, pre- and postoperative measurements of the distance between a fixed reference point and the base of the probeable pocket have been used to evaluate healing following therapy (probing attachment level; Ellegaard & L  e 1971, Ramfjord et al. 1975, Carraro et al. 1976, Yukna et al. 1976). In other studies the marginal alveolar bone has been probed under local anesthesia (probing bone level; Schallhorn et al. 1970, Dragoo & Sullivan 1973). Measurements to the exposed alveolar bone during therapeutic surgery and then again during an exploratory re-entry procedure have been used in studies by Patur & Glickman (1962), Donnenfeldt et al. (1970), Patur (1974), Froum et al. (1975a, b), Mellonig et al. (1976), Polson & Heijl (1978) and Sepe et al. (1978). Standardized radiographic techniques have also been used to determine the bone level changes (Patur & Glickman 1962, Dragoo & Sullivan 1973, Rosling et al. 1976a, b).

Different clinical methods to evaluate healing following therapy have been used in different studies and complicates the evaluation of these studies. In addition, each of the clinical methods has given limitations. During probing for the attachment level, the location of the tip of the probe in relation to the apical end of the junctional epithelium is unknown to the clinician. Before therapy, in the presence of inflammation, the probe tip may penetrate beyond the apical termination of the junctional epithelium and into the subjacent connective tissue. After therapy, in more healthy condition, the probe tip may stop within the junctional epithelium short of the connective tissue attachment. The probe tip penetration also varies with the probing force and the diameter of the probe tip (Listgarten 1980, van der Velden & Jansen 1980, Caton et al. 1981, Jansen et al. 1981, Fowler et al. 1982).

Probing bone measurements and open bone recordings may both be adequate to determine changes in bone height, but do not offer documentation of new connective tissue attachment. It has been reported that a junctional epithelium may persist along the root surface adjacent to newly formed bone in osseous defects (Caton & Zander 1976, Listgarten & Rosenberg 1979, Moskow et al. 1979). The limitations of radiographs in evaluation of regenerative results are also apparent (Friedman 1958, Goldman & Stallard 1973). Although the precision of alveolar landmark measurements

can be improved by standardization of the methodology (Rosling et al. 1975), the interpretation of the radiographic image remains a problem.

Histologic observations: In order to verify new attachment, e.g. new connective tissue and cementum formed on a root surface which previously was part of an epithelialized pocket, biopsies of the treated teeth and histological observations need to be used. Also, the extension of the preoperative pocket needs to be properly demarcated. In several reports a notch in the root surface at the fundus of the osseous defect has been used as a reference point for histological observations (Ross & Cohen 1968, Dragoo & Sullivan 1973, Hiatt et al. 1978, Bowers et al. 1982). This notch is useful for comparative measurements of different treatment modalities, but is inconclusive for the purpose of determination of true new attachment. A notch placed through existing subgingival calculus on the root surface has been utilized for this latter purpose (Cole et al. 1980, Froum et al. 1983).

Histological observations of biopsies of treated teeth can be used in humans on rare occasions only. Therefore, most studies have relied upon clinical methods of evaluation.

RESULTS OF THERAPY

Full coverage flap surgery: Osseous defects treated by full coverage flap surgery in patients that were seen for frequent postoperative prophylaxis demonstrated a mean gain of probing attachment level amounting to 3.5 mm and a mean gain of roentgenographic bone support of 2.8 mm (Rosling et al. 1976a). Complete bone fill in 11 out of 15 intraosseous defects and a mean bone apposition of 2.5 mm was reported by Polson & Heijl (1978). In some recent studies less gain of probing attachment levels and less bone regeneration have been reported. Isidor (1981) found a mean gain of probing attachment level following replaced flap surgery amounting to 0.7 mm and Froum et al. (1982b) demonstrated 1.4 mm gain of probing attachment level and 1.2 mm bone regeneration.

Denudation procedure: Rosling et al. (1976b) compared five different treatment modalities. One of these, the apical positioned flap, seems similar to the denudation procedure described by Prichard (1957, 1983).

Bone regeneration, measured on radiographs, amounted to 1.9 mm as compared to 3.1 mm in lesions treated with full coverage flap procedure.

Osseous resection: The study by Rosling et al. (1976b) showed that apically positioned and full coverage flap procedures involving bone resection resulted in mean radiographic bone fill of intraosseous defects amounting to 0.9 and 1.1 mm respectively. This was less than the radiographic bone fill observed following these procedures without bone resection which amounted to 1.9 mm and 3.1 mm respectively. The resective approach leads to some loss of attachment and bone in areas adjacent to the defect (Donnenfeldt et al. 1970, Moghaddas & Stahl 1980, Rosling et al. 1976b).

Osseous grafting procedures: The prospects of enhancing the regenerative potential with the use of osseous grafts have initiated numerous studies using different osseous graft materials (Ross & Cohen 1968, Halliday 1969, Schallhorn et al. 1970, Rosenberg 1971, Schallhorn & Hiatt 1972, Hawley & Miller 1975, Froum et al. 1975a,b, Mellonig et al. 1976, Hiatt et al. 1978, Sepe et al. 1978, Listgarten & Rosenberg 1979, Moskow et al. 1979, Quentero et al. 1982, Sanders et al. 1983).

Several of the above reports claim a mean bone fill amounting to 3-4 mm. Other studies have obtained more limited bone regeneration of around 1 mm (Patur 1974, Altieri et al. 1979). Some studies with comparisons between grafted and non-grafted control areas show more bone fill following grafting (Carraro et al. 1976, Froum et al. 1976). Others fail to show differences between grafted and non-grafted areas (Altieri et al. 1979).

A survey of histological data from biopsy material by Bowers et al. (1982) was interpreted to indicate that new bone and new cementum is more likely to occur when various grafts are used than when no grafts are used.

Schallhorn et al. (1970) reported comparable results following treatment with iliac allografts, iliac autografts and intraoral bone and marrow grafts. Nielsen et al. (1981) observed no difference comparing autogenous cancellous bone and bovine osseous grafts.

Non-surgical therapy: Isidor (1981) compared the effect of root planing alone with two surgical modalities in intraosseous defects. A limited average gain of probing attachment were seen in all three groups. The means indicate slightly more gain of probing attachment after root planing than after the surgical therapies, 1.4 mm compared to 0.5 mm and 1.0 mm respectively.

CITRIC ACID DEMINERALIZATION OF THE ROOT SURFACE

Experimental studies in animals: Register (1973) and Register & Burdick (1975, 1976) demonstrated that surface demineralization of surgically denuded root surfaces using topical application of acid resulted in accelerated reattachment and formation of cementum when compared to non-demineralized control surfaces. Citric acid, pH1, applied during 2-3 minutes were reported to give optimal effects (Register & Burdick 1975).

In an experimental model in dogs characterized by chronic through-and-through furcation defects, new connective tissue attachment including formation of new cementum was found in a majority of the acid treated defects, whereas all of the non-acid treated controls became re-epithelialized following the surgical therapy (Crigger et al. 1978, Nilvéus et al. 1980). The potential for regeneration after citric acid treatment of the root surfaces in large through-and-through furcations with concomitant horizontal bone reduction in dogs and monkeys was reported in a study by Klinge et al. (1981). Bogle et al. (1981, 1983) demonstrated the biological possibility of obtaining new attachment in naturally occurring periodontal disease using citric acid conditioning.

The difference in healing response between citric acid treated specimens as compared to controls was confirmed in reimplantation experiments by Polson & Proye (1982) and Proye & Polson (1982). After extraction of teeth in monkeys the coronal third of the periodontal ligament was removed by root planing. Before reimplantation of the teeth, the denuded area of the root surface was citric acid treated in half the number of specimens, whereas the other specimens were reimplanted as non-acid treated controls. During healing the junctional epithelium migrated rapidly along the denuded non-acid treated root surfaces, but not along the citric acid treated surfaces. Healing in acid treated areas was established through a connective tissue attachment.

Nyman et al. (1981) used rubber elastics to create periodontal breakdown in monkeys. A notch was placed at the level of the alveolar crest at the time of surgical therapy. Citric acid treatment of the root surface after root planing was compared to root planing alone. No difference between acid treated and non-acid treated controls was found in this study. The apical extension of the junctional epithelium was located at or close to the notch in both groups.

Histological studies in humans: Stahl & Froum (1977) studied 6 teeth in one patient following surgical treatment and citric acid conditioning. No evidence suggesting that citric acid application would facilitate cementogenesis and connective tissue attachment was observed. Cole et al. (1980) studied the healing response following surgery and citric acid conditioning on 9 condemned teeth scheduled for extraction and having subgingival calculus. During the surgical procedure a notch was placed into the root by cutting through the apical portion of existing subgingival calculus. All specimens demonstrated new cementum and soft connective tissue coronal to the notch. The results demonstrated that connective tissue regeneration on previously diseased root surfaces in humans is a biological possibility. The results by Cole et al. (1980) have been confirmed in a recent study by Froum et al. (1983).

Albair et al. (1982) demonstrated connective tissue attachment coronal to a notch placed at the alveolar bone crest during surgery in 6 out of 9 citric acid treated teeth. Five control teeth without citric acid conditioning demonstrated a long junctional epithelium.

The effects of citric acid conditioning on attachment following laterally positioned flaps were studied by Common & McFall (1983). Pairs of teeth with localized gingival recession on the facial aspect of mandibular incisors scheduled for extraction were treated in five patients. A reference notch was placed just coronal to the bone crest. One tooth of each pair served as non-acid treated control and the other was treated with citric acid for two minutes. New cementum and connective tissue attachment were reported coronal to the notch in all citric acid treated specimens, whereas a long junctional epithelium was found in all the control teeth.

Clinical studies in humans: In a study by Cole et al. (1981) full thickness flap surgery with or without citric acid conditioning of the exposed root surfaces was compared. A mean probing attachment level gain for acid treated surfaces of 2.1 mm was obtained as compared to 1.5 mm for the non-acid treated control surfaces. Successful clinical results were reported following acid conditioning in conjunction with mucogingival procedures by Liu & Solt (1980) and Shiloah (1980).

Biomechanism of connective tissue attachment following citric acid treatment: Acid treatment of a planed root surface will expose dentinal tubules and a network of collagen fibrils (Garrett et al. 1978, Daryabegi et al. 1981, Fernyhough & Page 1983, Lasho et al. 1983). The depth of demineralization of root planed dentin following use of citric acid for 2-3 minutes amounts to 3-5 μm (Garrett et al. 1978).

In an electron microscopic study of periodontal wound healing following acid conditioning the exposed collagen fibrils of the dentin matrix were observed to interdigitate with newly formed collagen fibrils after 7-14 days (Ririe et al. 1980). This interdigitation may limit the apical migration of the junctional epithelium and provide connective tissue attachment to the root surface as opposed to a long junctional epithelium. Polson & Proye (1982) suggested that a fibrin linkage to the exposed collagen fibrils on the acid treated root surface is a precursor to the connective tissue linkage. Another suggested explanation for the enhanced healing following citric acid treatment is through chemical detoxification of the diseased root surface. However, contradictory results regarding the ability of citric acid to extract root surface contaminants have been reported (Fine et al. 1980, Sarbinoff et al. 1983).

CONCLUSIONS FROM PREVIOUS STUDIES

The following conclusions can be made from the previous research:

- Using a variety of clinical measurements regeneration of periodontal intraosseous defects have been reported following surgical as well as non-surgical procedures.

- Contradictory results regarding the improvements following similar therapies of intraosseous defects have been reported.
- It is uncertain whether osseous grafting enhances regeneration.
- At present there seems to be no treatment procedure which predictably enables regeneration in periodontal intraosseous defects.
- Citric acid treatment of the root surface has been shown to be a fairly predictable method of obtaining new attachment in animals.
- The possibility of obtaining new attachment in humans have been demonstrated using citric acid conditioning of the root surface.
- The number of osseous walls adjacent to the defect may effect the healing response following therapy.

PURPOSES OF INVESTIGATIONS

The purposes of the present series of studies were:

- To compare different clinical methods to evaluate healing after regenerative surgery of intraosseous defects.
- To find out if citric acid conditioning of the root surface would predictably improve the healing results following therapy of intraosseous defects as compared to replaced flap surgery alone.
- To find out if cancellous bone grafting in intraosseous defects would further enhance the regenerative potential of citric acid conditioning.
- To study, if osseous recontouring for pocket reduction purposes would compromise the regenerative potential of citric acid conditioning.
- To compare the difference in clinical results between a surgical procedure using acid conditioning contrasted to a re-rootplaning procedure.
- To find out if certain defect characteristics might influence the healing response following therapy.

MATERIAL AND METHODS

PAPER I

In **Paper I** four clinical methods to evaluate healing after reconstructive therapy of intraosseous defects were compared:

1. probing attachment level
2. probing bone level
3. entry/re-entry bone height measurements
4. radiographic bone height determinations.

Also, the reproducibility of repeated measurements of probing attachment level and probing bone level was studied. 13 patients with a total of 33 defects volunteered for the study.

Probing attachment level was measured using a specially machined probe tip having 1 mm increments and 0.5 mm diameter. Recordings to the nearest 1 mm were made from buccal and lingual aspects of the proximal defect sites. A metal onlay was used to provide reference points for the measurements. The positioning of the probe tip was guided by buccal and lingual steering grooves placed in the onlays. Probing attachment level was recorded from the edge of the onlay to the tip of the probe.

Immediately after probing attachment level measurements were completed, probing bone level measurements were taken under local anesthesia. These recordings were obtained using the same probe tip and metal onlay as for probing attachment level measurements.

The bone level at the apical extent of the defects was determined after removal of soft tissues from the defects during reconstructive surgery and subsequently during an exploratory re-entry procedure. Measurements were again taken using the same buccal and lingual steering grooves of the onlays.

Radiographs were obtained under standardized conditions using bite-block and film holders attached to the long cone of the X-ray apparatus. Pre- and postoperative films from all patients were coded, mounted and randomly projected for measurements using 10 X magnification. Fixed

referencepoints for measurements were selected; e.g. restoration margins, clearly identifiable cemento-enamel junctions or proximal contact points. The vertical distance from such reference points to the apical extent of the radiographic intraosseous defects was measured in mm. All measurements from the radiographs were made at the completion of the study.

PAPERS II-V

In **Papers II-V** the healing response following different treatment modalities of intraosseous defects was evaluated.

SUBJECTS

A total of 62 patients participated in the four studies (13, 19, 16 and 14 patients respectively). Initial therapy consisting of oral hygiene instruction and root planing was performed prior to final patient and site selection.

In **Papers II, III and V** a minimum of two areas, each with radiographic evidence of an intraosseous lesion and a residual probing depth ≥ 6 mm was required for each patient.

In **Paper IV** patient selection was based on the following criteria at reevaluation; 1) Presence of at least one proximal area with a residual probing depth ≥ 7 mm; 2) An associated intraosseous defect which was proven to be ≥ 5 mm deep as measured during surgery.

CLINICAL PARAMETERS

The following parameters were recorded:

1. Plaque scores
2. Probing pocket depth
3. Probing attachment level
4. Probing bone level
5. Osseous defect circumference
6. Number of tooth surfaces involved
7. Number of osseous walls of the defects
8. Depth of 3+2+1-, 3+2- and 3-wall components of the osseous defects.

The above listed parameters were supplemented with the following parameters in one or several Papers:

9. Bleeding upon probing (**Papers III-V**)
10. Postoperative soft tissue crater depth (**Papers III and V**)
11. Immediate postoperative probing depths (**Papers IV and V**)
12. Gingival recession (**Paper IV**)
13. Immediate postoperative probing attachment change (**Paper V**).

Plaque scores: Six aspects of each tooth were examined: mesio-buccal, mid-buccal, disto-buccal, mesio-lingual, mid-lingual and disto-lingual. Plaque was disclosed with an erythrosine dye (Diaplac[®], Astra, Sweden or Trace[®], Lorvic Corporation, St. Louis, MO, U.S.A.). Areas adjacent to the gingival margin which exhibited a deep stain that could be easily removed with the side of a probe were scored as having plaque. Plaque scores were expressed as the percentage of total surfaces under evaluation which revealed the presence of plaque.

Two types of plaque scores were calculated: 1) full mouth plaque scores, based upon the six aspects of all teeth in the mouth, 2) local site plaque scores, based upon the buccal and lingual aspects of the proximal surface involved by the defect. Mean postoperative full mouth and mean postoperative local site plaque scores were averages based upon calculations from the recordings at 6, 12, 18 and 24 weeks postoperatively. In **Paper III** mean plaque scores are based on recordings at 6 and 12 months postoperatively only.

Probing pocket depth and probing attachment level: In **Papers III, IV and V** measurements of probing pocket depth and probing attachment level were made using an electronic pressure sensitive probe (Electronic Periodontal Probe, Model 200, Vine Valley Research, Middlesex, N.Y., U.S.A.). Each site was probed using a standardized force of 0.75 N. The pressure sensitive probe was not used in **Paper II**. A specially machined probe tip having 1 mm increments and 0.5 mm diameter was used. Recordings to the nearest 0.5 mm were made from the buccal and lingual aspects of the proximal defect sites. A soft acrylic onlay was used to provide reference points for the probing measurements. During measurements the probe was directed apically toward the deepest point of the mid-proximal aspect of the root surface. Probing pocket depth was measured from the

gingival margin to the tip of the probe. Probing attachment level was recorded from the onlay margin to the tip of the probe. Means of the buccal and lingual recordings for each proximal defect were used to evaluate the effect of treatment.

In **Paper IV** tooth surfaces adjacent to the defect were also measured (buccal and lingual of defect tooth, proximal, buccal and lingual of adjacent tooth).

Probing bone level: Immediately after probing pocket depth and probing attachment level measurements were completed, probing bone level measurements were taken under local anesthesia using the same probe tip. The probe was directed apically toward the mid-proximal aspect of the root surface and forced through the soft tissue toward the bone until definite resistance was met. The probing bone level was recorded as the distance from the onlay margin to the probe tip. Means of buccal and lingual recordings were calculated.

Osseous defect circumference, number of tooth surfaces involved and number of osseous walls of the defects: These characteristics were recorded from the surgically treated defects only, and after surgical debridement of the defect sites. The circumference of the osseous defect at the coronal portion of the defect in relation to the root circumference was estimated to the nearest 30°. The number of tooth surfaces involved at the apical portion of the defect was recorded as 1 if the defect was localized to the proximal surface only, as 2 when the defect also encompassed the buccal or lingual surface and as 3 when proximal, buccal and lingual surfaces were involved. The number of osseous walls of the defects was recorded as 1 when only a proximal wall was present, as 2 if the proximal defect had a buccal or lingual wall and as 3 when both buccal and lingual walls were present.

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Depth of 3+2+1-, 3+2- and 3-wall components of the osseous defects: The osseous defect depth was recorded using the onlay margin as reference point for a series of measurements (Fig.1).

The distance to the fundus of the proximal defect (F) was measured from both buccal (SB) and lingual (SL) onlay margins. The crest of the buccal wall of the defect (B) was measured from the buccal onlay margin. The

crest of the lingual wall of the defect (L) was measured from the lingual onlay margin. In **Papers II and III** the crest of the proximal wall (P) of the defect was measured from the buccal onlay margin. In **Papers IV and V** the crest of the proximal wall of the defect was measured from both buccal and lingual onlay margins.

The height of the buccal wall was calculated by subtracting its crest level measurement from the buccal measurement of the fundus. Similarly, the lingual wall height was calculated from the corresponding lingual measurements. To calculate the height of the proximal wall the buccal measurement of its crest or the average of the buccal and lingual measurements of its crest was subtracted from the average of the buccal and lingual measurements of the fundus of the defect.

In this way, the depths of the defects could be expressed relative to the number of walls of the defect. The depths were calculated for the 3-wall, 3+2-wall and 3+2+1-wall components of the defects (Fig.1). The figures give only approximate representation of the defect components due to the fact that angulation of the probe had to be varied to obtain the different measurements.

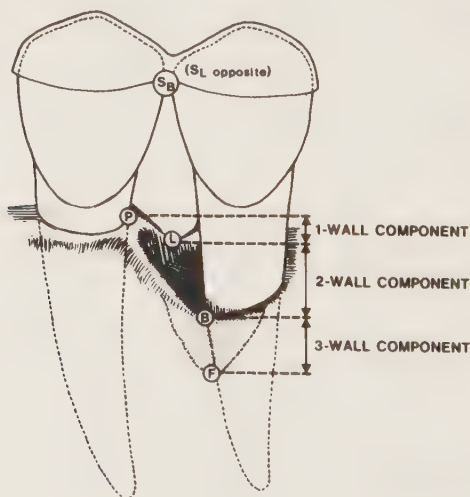


Fig.1. Schematic illustration of a proximal osseous defect and points of measurements to calculate the depths of the 3-, 3+2- and 3+2+1-wall components of the defects (see text).

Bleeding upon probing: Bleeding upon probing for the defect sites was recorded following the pocket probing and using a probing force of 0.50 N. Probing for full mouth bleeding scores were also performed using 0.50 N.

In **Paper III** mean postoperative full mouth and local site bleeding scores were calculated from the recordings at 6 and 12 months. In **Paper IV** only final recordings were taken. In **Paper V** mean postoperative full mouth and local site bleeding scores were calculated from the recordings at 12, 18 and 24 weeks postoperatively.

Postoperative soft tissue crater depth: The depths of interdental soft tissue craters were measured from the buccal aspect. The distance from the onlay margin to the most apical point of the crater was first measured. Then, the distance from the onlay margin to the most coronal extent of the buccal crater wall was recorded. The crater depth was calculated by subtracting the buccal wall measurement from the apical point measurement. Again, the computed depths are approximate crater depths due to the difference in probe angulation for the two readings. The measurements were taken using a minimum of force to avoid compression of the soft tissues.

Immediate postoperative probing depth: Following suturing the distance from the gingival margin to the fundus of the bony defect was measured. Means of buccal and lingual recordings were calculated.

Immediate postoperative probing attachment change: Immediately postoperatively the distance from the stent margin to the fundus of the bony defect was measured. This distance was subtracted from the preoperative attachment level measurement to determine the immediate postoperative probing attachment change. Means of buccal and lingual recordings were calculated.

Gingival recession: Gingival recession was calculated by change in the distance from the onlay margin to the gingival margin at postoperative intervals compared to baseline.

TREATMENT PROCEDURES

Full thickness flap surgery: Buccal and lingual mucoperiosteal flaps were raised to expose the intraosseous lesion. Granulomatous tissue was removed and the osseous walls of the defect were uncovered. The root surfaces were carefully planed and irrigated with saline. Osseous recontouring was not performed. The flaps were replaced and sutured to obtain complete closure of the wounds.

Full thickness flap surgery with citric acid treatment of the root surfaces: Buccal and lingual mucoperiosteal flaps were raised to expose the intraosseous lesion. Granulomatous tissue was removed and the osseous walls of the defect were uncovered. The root surfaces were carefully planed. Following bleeding control the root surfaces were treated by a 3 minute topical application of saturated citric acid (pH1) using cotton pledgets, followed by thorough irrigation with saline or water. Osseous recontouring was not performed. The flaps were replaced and sutured to obtain complete closure of the wounds.

Full thickness flap surgery with citric acid treatment of the root surfaces and cancellous bone grafts: Following the surgical procedure including citric acid treatment cancellous bone grafts obtained from the maxillary tuberosity area were placed in the defects. The bone material was obtained using a rongeur, the cortical layer removed and the material was cut into small pieces.

Full thickness flap surgery with citric acid treatment of the root surfaces and partial osseous resection: Defects assigned the partially resective approach were treated by osseous reduction as part of the surgical procedure. The extent of the osseous reduction that was performed varied due to concern about sacrificing supporting bone, yet the reduction was enough to assure an immediate postoperative probing depth of ≤ 6 mm.

Root planing: Defects to be root planed were instrumented with curettes under local anesthesia. Intentional soft tissue curettage was not performed.

Postoperative treatment: Chlorhexidine (Hibitane[®], ICI, Macclesfield, Great Britain) was prescribed for twice daily, 0.2 % rinses to supplement the oral hygiene procedures during the first two-three postoperative weeks.

Sutures and dressing (if used) were removed one week after surgery. The patients were seen at weekly intervals during the first three postoperative weeks and then again another three weeks later (six weeks postoperatively) for oral hygiene reinstruction and polishing of the teeth. Subsequently, the patients were seen every six weeks for oral hygiene reevaluation and tooth cleaning. No deep scaling or soft tissue curettage of the experimental sites was made at these appointments.

PAPER VI

In **Paper VI** the relationship between defect characteristics and the parameters of healing was determined using multiple regression analysis. Using each of probing attachment level change, probing bone level change and residual probing depth as independent variable and compensating for patient variability partial coefficients of correlation were calculated for the various defect characteristics.

84 periodontal intraosseous defects in 51 patients were analyzed with respect to:

1. probing pocket depth
2. probing attachment level
3. probing bone level
4. number of tooth surfaces involved
5. osseous defect circumference
6. number of osseous walls of the defect
7. depth of 3+2+1-, 3+2- and 3-wall components of the defect.

The defects studied in **Paper VI** were part of the material of **Papers II-V**. Only defects treated with the same surgical procedure (full thickness flap surgery with citric acid root conditioning), recorded with the same parameters, and having complete data for all investigated parameters were included.

RESULTS

In Paper I it was found that the depth of the lesion recorded by the various methods showed differences which seem to relate to the varying nature of the methods. On the average, the periodontal probe penetrated 0.8 mm deeper during probing for bone than during probing for attachment level and another 0.3 mm deeper after denudation of the lesions during entry/re-entry.

A high degree of correlation was found between all three probing methods when the changes following therapy for the individual sites were compared ($r=0.85$, 0.75 and 0.81 respectively). Radiographic bone height showed lower degrees of correlation with all three probing parameters ($r=0.45$, 0.46 and 0.47 respectively). The reproducibility of the probing bone level measurements seemed to be somewhat better than the probing attachment level scores.

In Paper II the initial mean probing pocket depth of 7.7 mm for the acid treated defects was reduced to a mean residual probing depth of 4.3 mm. This 3.4 mm reduction was accomplished by a mean gain of probing attachment level of 2.1 mm and 1.3 mm of mean gingival recession (Fig.2).

For the non-acid treated controls the mean preoperative probing pocket depth of 7.5 mm was reduced to a mean residual probing depth of 4.7 mm. This 2.8 mm reduction was accomplished by a mean gain of probing attachment level of 1.2 mm and 1.6 mm of mean gingival recession.

The probing bone level showed a mean gain of 1.5 mm in the acid treated group as compared to 0.9 mm in the control group.

Analysis of variance showed statistically significant differences between the two treatment modalities for gain of probing attachment level ($p < 0.05$).

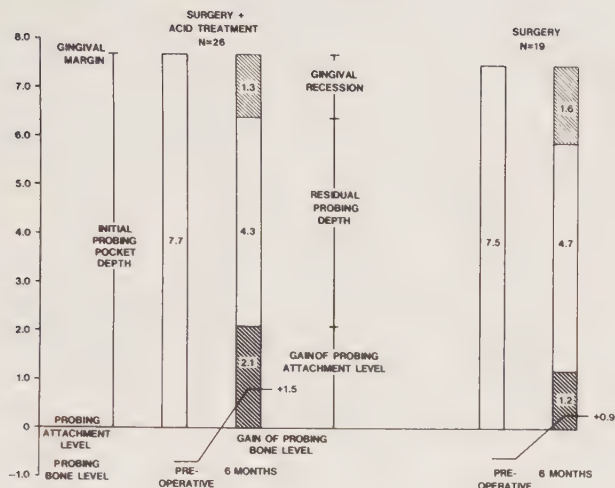


Fig.2. Schematic illustration of the mean effects of surgery supplemented and with citric acid treatment of the root surface and the effects of surgery alone. The figure shows what happened to the initial probing pocket depths in terms of the amounts of gingival recession, the amounts of gain of probing attachment level and the residual probing depth in mm. The pre- and postoperative probing bone levels relative to the probing attachment levels are also depicted.

In Paper III the initial mean probing pocket depth of 6.1 mm for the acid treated defects was reduced to a mean residual probing depth of 4.2 mm. This 1.9 mm reduction was accomplished by a mean gain of probing attachment level of 1.1 mm and a mean of 0.8 mm gingival recession (Fig.3).

For the acid treated and bone grafted sites, the mean preoperative probing pocket depth of 6.3 mm was reduced to a mean residual probing depth of 4.4 mm. This 1.9 mm reduction was accomplished by a mean gain of probing attachment level of 1.2 mm and 0.7 mm of mean gingival recession.

The probing bone level showed a mean gain of 0.8 mm in the acid treated sites and 1.2 mm in the acid treated and bone grafted areas.

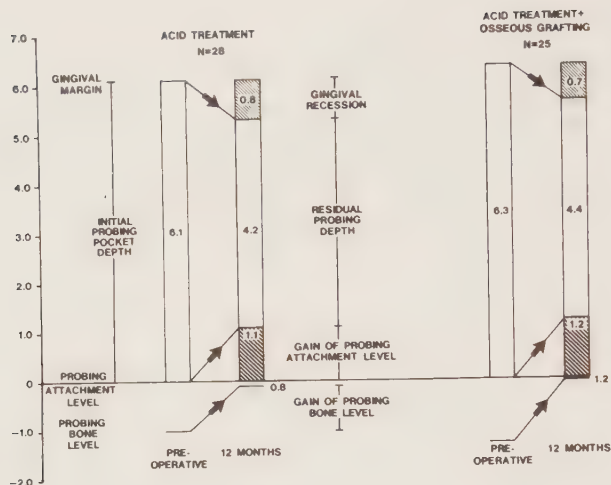


Fig.3. Schematic illustration of the mean effects of surgery supplemented with citric acid treatment of the root surface and the effects of surgery, citric acid treatment and osseous grafting.

In **Paper IV** the initial mean probing pocket depth of 7.9 mm for the non-resected sites was reduced to a mean residual probing depth of 5.3 mm. This 2.6 mm reduction was accomplished by a mean gain of probing attachment level of 1.1 mm and 1.5 mm of mean gingival recession (Fig.4).

For the partially resected sites, the mean preoperative probing pocket depth of 7.5 mm was reduced to a mean residual probing depth of 4.0 mm. This 3.5 mm reduction was accomplished by a mean gain of probing attachment level of 0.7 mm and 2.8 mm of mean gingival recession.

The probing bone level showed a mean gain of 1.2 mm in the non-resected group and 0.7 mm in the partially resected group.

Analyses of variance, accounting for the slight difference of preoperative probing pocket depth between the two groups, showed statistically significant differences between the two groups for residual probing depth ($p < 0.01$) but no significant differences for gain of probing attachment or gain of probing bone level.

Following therapy the partially resected group demonstrated significantly more loss of probing attachment level for the proximal, buccal and lingual surfaces of the adjacent teeth ($p < 0.05$) as compared to the non-resected group. The buccal and lingual surfaces of the defect teeth also demonstrated more loss of probing bone level in the partially resected than in the non-resected group ($p < 0.05$).

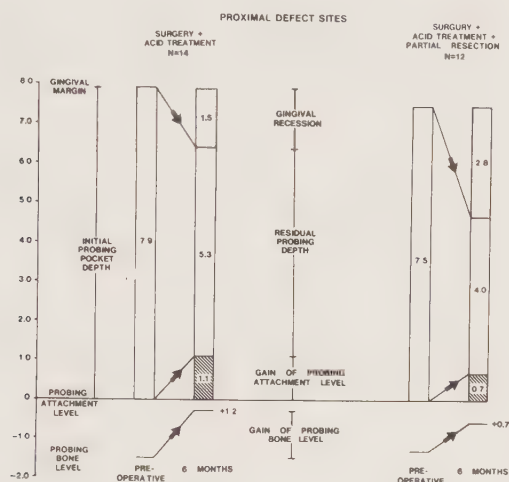


Fig.4. Schematic illustration of the mean effects of surgery supplemented with citric acid treatment of the root surface and the effects of surgery, citric acid treatment and partial osseous resection.

In Paper V the initial mean probing pocket depth of 6.8 mm for the acid treated sites was reduced to a mean residual probing depth of 4.1 mm. This 2.7 mm reduction was accomplished by a mean gain of probing attachment level of 1.3 mm and 1.4 mm of mean gingival recession (Fig.5).

For the root planed areas, the mean preoperative probing pocket depth of 6.7 mm was reduced to a mean residual probing depth of 5.2 mm. This 1.5 mm reduction was accomplished by a mean gain of probing attachment level of 0.8 mm and 0.8 mm of mean gingival recession.

The probing bone level showed a mean gain of 0.6 mm in the acid treated defects as compared to 0.2 mm in the root planed sites ($p < 0.01$).

The differences in gain of probing attachment level and residual probing depth between the two groups were statistically significant ($p < 0.05$ and $p < 0.001$).

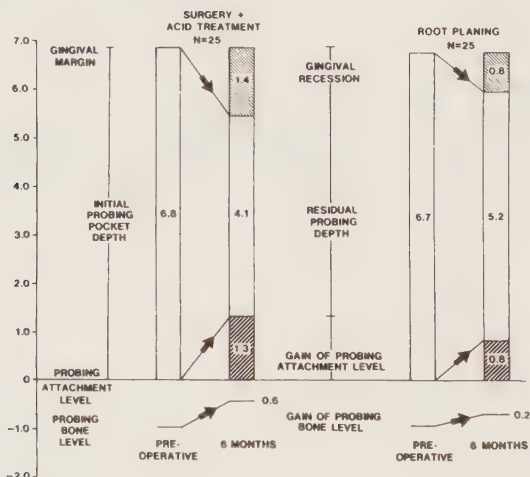


Fig.5. Schematic illustration of the mean effects of surgery supplemented with citric acid treatment of the root surface and the effects of root planing alone.

The combined data from **Papers II-V** for the total material of 174 defects is presented in Table 1.

A mean gain of probing attachment level of 1.2 mm was obtained following treatment. The probing bone level improved an average of 0.9 mm and the mean preoperative probing pocket depth of 6.9 mm was reduced to 4.5 mm.

Table 1. Pre- and postoperative records for the total material of 174 defects.

	Preop probing pocket depth (mm)	Change of probing attachment level (mm)	Change of probing bone level (mm)	Residual probing pocket depth (mm)
Mean	6.9	1.2	0.9	4.5
S.D.	1.4	1.0	1.1	1.3
Range	4.5-11.25	-1.5-5.5	-1.75-4.0	2.0-9.75

The 84 acid treated defects analyzed in **Paper VI** demonstrated a mean gain of probing attachment level amounting to 1.4 mm and a mean gain of probing bone level of 1.0 mm. The initial mean probing pocket depth was reduced from 7.0 mm to 4.4 mm. The changes following therapy expressed as the number and percentage of defects demonstrating different magnitude of probing attachment level and probing bone level changes are presented in Table 2.

Table 2. Number and percentage of defects demonstrating different magnitude of change of probing attachment level and probing bone level.

Magnitude of change (mm)	Change of probing attachment level		Change of probing bone level	
-1.25 - -2.00	1	(1 %)	1	(1 %)
-0.25 - -1.00	3	(4 %)	12	(14 %)
0.00 - 0.75	22	(26 %)	30	(36 %)
1.00 - 1.75	28	(33 %)	18	(21 %)
2.00 - 2.75	25	(30 %)	16	(19 %)
3.00 - 3.75	3	(4 %)	6	(7 %)
4.00 - 4.75	2	(2 %)	1	(1 %)
Total	84	(100 %)	84	(100 %)

The coefficients of correlation between various defect characteristics and the parameters of healing are presented in Table 3. The change of probing attachment level was significantly correlated to the preoperative probing pocket depth ($p < 0.01$) and to the depth of 3+2+1-wall component of the osseous defect ($p < 0.05$). The change of probing bone level was significantly correlated to the depths of the 3+2+1- and the 3+2-wall components of the defects ($p < 0.01$ and $p < 0.05$ respectively).

The residual probing depth showed significant correlations to preoperative probing pocket depth, number of tooth surfaces involved and defect circumference ($p < 0.01$, $p < 0.01$ and $p < 0.001$ respectively).

Although statistically significant the above coefficients of correlation were generally low (0.36 - 0.58) Table 3.

Table 3. Coefficients of correlation between various defect characteristics for the total material of 84 acid treated defects and the healing response as evidenced by change of probing attachment level, change of probing bone level and residual probing depth.

Defect characteristic	Coefficient of Correlation		
	Change of probing attachment level (mm)	Change of probing bone level (mm)	Residual probing depth (mm)
Preoperative probing pocket depth (mm)	0.47**	0.22	0.50**
Number of tooth surfaces involved	-0.11	-0.02	0.50**
Defect circumference (degrees)	-0.15	-0.14	0.58***
Number of osseous walls of defect	-0.02	0.28	-0.33
Depth of 3+2+1-wall component (mm)	0.36*	0.44**	0.13
Depth of 3+2-wall component (mm)	0.22	0.36*	0.27
Depth of 3-wall component (mm)	0.09	0.07	0.28

*: $p < 0.05$; **: $p < 0.01$; ***: $p < 0.001$.

Subsamples of the total material of 84 defects are presented in Tables 4 and 5. Table 4 presents defect characteristics for 30 sites which showed 2.0 mm or more gain of probing attachment level as opposed to the characteristics of 13 sites demonstrating no change or loss of probing attachment level. Table 5 presents defect characteristics for 23 sites which showed 2.0 mm or more gain of probing bone level as opposed to 22 sites demonstrating no change or loss of probing bone level. The tables reveal limited differences in defect characteristics between these polarized best responding and non-responding sets of defects.

Table 4. Characteristics of sites showing 2.0 mm or more gain of probing attachment level and sites demonstrating no change or loss of probing attachment level.

Defect characteristic	Change of probing attachment level	
	≥ 2.0 mm	≤ 0.0 mm
	(N=30) ($\bar{X}$: 2.4 $\pm$ 0.6 mm)	(N=13) ($\bar{X}$: -0.2 $\pm$ 0.4 mm)
Preoperative probing pocket depth (mm)	7.7 $\pm$ 1.9	6.7 $\pm$ 1.7
Number of tooth surfaces involved	1.9 $\pm$ 0.9	2.1 $\pm$ 1.0
Defect circumference (degrees)	137 $\pm$ 63	173 $\pm$ 98
Number of osseous walls of defect	2.5 $\pm$ 0.7	2.5 $\pm$ 0.7
Depth of 3+2+1-wall component (mm)	5.1 $\pm$ 2.2	4.9 $\pm$ 1.7
Depth of 3+2-wall component (mm)	4.0 $\pm$ 2.4	3.6 $\pm$ 1.9
Depth of 3-wall component (mm)	2.2 $\pm$ 1.9	2.1 $\pm$ 1.3

Table 5. Characteristics of sites showing 2.0 mm or more gain of probing bone level and sites demonstrating no change or loss of probing bone level.

Defect characteristic	Change of probing bone level	
	≥ 2.0 mm	≤ 0.0 mm
	(N=23) ($\bar{X}$: 2.5 ± 0.6 mm)	(N=22) ($\bar{X}$: -0.3 ± 0.3 mm)
Preoperative probing pocket depth (mm)	7.8 ± 2.1	6.7 ± 1.3
Number of tooth surfaces involved	2.0 ± 0.9	1.8 ± 0.9
Defect circumference (degrees)	134 ± 65	153 ± 91
Number of osseous walls of defect	2.4 ± 0.7	2.5 ± 0.6
Depth of 3+2+1-wall component (mm)	5.6 ± 2.2	4.0 ± 1.8
Depth of 3+2-wall component (mm)	4.8 ± 2.3	3.0 ± 1.7
Depth of 3-wall component (mm)	2.8 ± 2.0	1.9 ± 1.3

DISCUSSION

The first step in the present series of research was to compare four clinical methods commonly used to evaluate the healing response following reconstructive periodontal therapy. It was anticipated that analysis of the relationships between the methods would indicate whether the four methods are supplementary to each other and should all be used in further studies, or, if one or more of the methods could conveniently be omitted.

A high degree of correlation was found between the three probing methods when the change following therapy for the individual sites was compared.

The difficulties in assessing changes of alveolar bone height in radiographs were demonstrated by the weaker correlation between the radiographic determinations and the changes as recorded by the probing parameters. The results of **Paper I** indicate that probing attachment level measurements alone would be sufficient of the presently available clinical examination methods for studies evaluating the effect of reconstructive periodontal therapy. However, if there are reasons to believe that the therapy to be evaluated may affect regeneration of soft connective tissue and bone differently both probing attachment level and probing bone level measurements should be used.

The introduction of periodontal probes that allow selection and standardization of the probing force (van der Velden & de Vries 1978, Polson et al. 1980) may further improve probing attachment level measurements. A standardized probing force was used in **Papers III-V**, eliminating the possibility of inadvertently introducing a lesser probing force post-operatively, which may result in a higher magnitude of recorded probing attachment level gain (Proye et al. 1982, Chamberlain et al. 1984b).

The limitations of probing measurements in order to determine the precise nature of the healing response following therapy need to be considered. Changes in probing attachment level measurements do not necessarily reflect histological changes in connective tissue attachment (Listgarten 1980, Magnusson & Listgarten 1980, Fowler et al. 1982).

Probing bone measurements may be adequate to determine changes in bone height but do not offer documentation of new connective tissue attachment. It has been reported that a junctional epithelium may persist along the root surface adjacent to the newly formed bone in osseous defects (Caton & Zander 1976, Listgarten & Rosenberg 1979, Moskow et al. 1979).

In spite of the above limitations, therapeutic studies have to rely upon clinical methods of evaluation. The results, however, have to be interpreted with these limitations in mind.

The results presented in **Papers II-V** demonstrate that short term clinical improvements can be accomplished following treatment of intra-osseous periodontal defects using a variety of treatment modalities. The magnitude of these improvements was limited. The mean gain of attachment

as a result of therapy varied in the different papers between 0.7-2.1 mm, mean for all 174 defects amounted to 1.2 mm. Corresponding figures for gain of probing bone levels were 0.2-1.5 mm with a mean value for all treated defects of 0.9 mm. These improvements are less than what have been reported by several authors following treatment of intraosseous defects (Carraro et al. 1976, Froum et al. 1975a, Rosling et al. 1976a, Polson & Heijl 1978, Movin & Borring-Møller 1982), but comparable to what have been reported by others (Altieri et al. 1979, Isidor 1981, Froum et al. 1982b). Differences in case selection, standardization of measurements, length of the preoperative treatment period and the postoperative care are factors that may influence the results following treatment of intraosseous defects.

In each of the **Papers II-V** full thickness flap surgery with citric acid treatment of the root surface was used as one mode of treatment. In **Paper II** acid conditioning resulted in somewhat more gain of attachment levels as compared to non-acid treated controls. However, the overall mean gain of attachment for all acid treated defects in **Papers II-V** (1.4 mm) suggests, that acid conditioning of the root surface had limited effect. This contrasts previous findings in dogs and monkeys where acid conditioning has been found to be a prerequisite to achieve new attachment (Crigger et al. 1978, Nilvéus & Egelberg 1980, Nilvéus et al. 1980, Klinge et al. 1981). The contrasting human and animal results emphase that extrapolation of results from experimental animal models to human situations should be made with extreme caution.

The lower rate of success in humans as compared to the results obtained in animals could possibly be explained by a difference in "healing potential" between the species. Also, animal experimentation has shown that the wound closure seems to be critical in order to prevent reepithelialization of the treated root surfaces (Klinge et al. 1981, 1984a,b). A correspondly exact wound closure may be difficult or impossible in humans due to anatomical differences.

In **Paper III** two methods to enhance regeneration following surgical treatment of periodontal defects was studied. Both therapies, e.g. citric acid conditioning alone and acid conditioning combined with osseous grafting resulted in approximately 1 mm gain of probing attachment and probing bone levels. Thus, the use of bone grafts failed to enhance the

regeneration in this material. One possible explanation for this lack of difference may be use of comparatively shallow sites. Osseous grafts may be of value primarily in deep defects. However, previous studies comparing osseous grafting to non-grafting procedure have obtained varying results regarding the value of osseous grafts (Carraro et al. 1976, Froum et al. 1976, Altieri et al. 1979, Pearson et al. 1981, Movin & Borring-Møller 1982). Therefore, the results of Paper III could represent an overall lack of significant effect of osseous grafts.

The objective of Paper IV was to determine if a partially resective surgical approach to the treatment of intraosseous periodontal defects would result in less residual probing depth as compared to a non-resective approach, yet not compromise the potentials for gain of probing attachment level and probing bone level. Significant differences in residual probing depth were observed and both treatments resulted in a mean gain for both probing attachment and probing bone levels of approximately 1 mm. Thus, it seems as partial osseous resection can be performed without reducing the regenerative capacity. In areas adjacent to the defect sites a general loss of probing attachment and probing bone levels similar to what have been reported by others were found (Donnenfeld et al. 1970, Moghaddas & Stahl 1980). The greater loss in adjacent areas of the partially resected group can be related to the osteoplasty and osteotomy performed in this group.

In Paper V, root planing alone was compared to surgery with citric acid conditioning. The results are somewhat contradictory to the findings by Isidor (1981), who observed a tendency towards more gain of probing attachment following root planing alone compared to full coverage flap surgery. There seems to be no apparant explanation to these differences in results. However, the differences between root planing alone and surgery in the study by Isidor (1981) were small and not statistically significant. Also, the mean gains of probing attachment levels in both the studies by Isidor (1981) and in Paper V are limited and within the 0.5-1.5 mm range. In fact, the similarity of results between root planing and surgery may question the justification of surgical procedures, at least on a short term basis.

The absence of bone fill following root planing is probably explained by the nature of this procedure. Root planing will leave most of the chronic

inflammatory tissue behind in the defect and will not remove the connective tissue adjacent to the osseous walls. These remaining tissues may prevent or retard bone apposition which may be facilitated by a surgical denudation followed by formation of a coagulum next to the defect walls.

Strictly, the observed findings of the relationship between defect characteristics and parameters of healing in **Paper VI**, apply to surgically treated and citric acid conditioned defects only. However, there are no apparent reasons to believe that the relationship would be different for non-acid treated defects.

The change of probing attachment level was significantly related to the preoperative probing pocket depth. This is in agreement with several studies on the effect of non-surgical and surgical periodontal therapy (Knowles et al. 1979, Hill et al. 1981, Pihlstrom et al. 1981, Lindhe et al. 1982a,b, Badersten et al. 1984a,b). The change of probing bone level was significantly related to the depths of the 3+2+1-wall and 3+2-wall components of the defects. This is in agreement with the suggestions by Froum et al. (1975a) that the total amount of osseous tissue surrounding the defect or the depth of the osseous defect may determine the amount of bone apposition in the lesions following therapy.

The number of osseous walls of the defects, the defect circumference, and the number of tooth surfaces involved showed little or no relationship with bone fill. These lacks of relationships are contradictory to several previous observations (Schaffer 1958, Patur & Glickman 1962, Wade 1966, Ellegaard & Löe 1971, Prichard 1972, Carraro et al. 1976, Quentero et al. 1982) but in agreement with the suggestion by Froum et al. (1975a) and the findings of Polson & Heijl (1978). In **Paper V** and in the study by Polson & Heijl (1978) more systematic and objective recordings of the defect characteristics were used. This approach is desirable from a scientific point of view in our attempts to analyze the current relationships. However, a subjective evaluation of the overall defect type which may include the examiners' bias of the expected healing response may still have its merit and explain why several studies have observed a positive relationship between bone fill and number of osseous walls and a negative relationship to the number of tooth surfaces involved.

In spite of the fact that some defect characteristics showed statistically significant relationship to the parameters of healing, the coefficients of correlation were generally low. A comparison of the best responding defects (2.0 mm or more gain of probing attachment or probing bone level) with the non-responding defects (no change or loss) revealed limited or no differences between these polarized groups (Paper VI). These findings seem to indicate that the outcome of treatment of intraosseous defects may be difficult to predict based upon evaluation of defect characteristics. Also, the limited overall amount of regeneration observed in Papers II-V seems to imply that clinically significant regeneration can not be anticipated following treatment of the "average" osseous defect. Nevertheless, the results from the analysis of the 84 acid treated defects in these studies show that in about 30 % of the defects regeneration of clinically significant amount can be accomplished (≥ 2.0 mm). Also the quality of attachment following surgery and citric acid treatment may be different from what can be expected as a result of other therapies. Further studies should aim at improving the predictability of clinically significant amounts of regeneration in intraosseous defects.

CONCLUSIONS

The following conclusions can be made from the present series of studies:

1. The amount of regeneration that can be accomplished in the "average" osseous defect seems to be limited.
2. Clinically significant regeneration can be obtained in some treated defects.
3. The treatment outcome of intraosseous defects may be difficult to predict.
4. On a short term basis, surgery with citric acid application seems to be a slightly more favorable method of treatment than re-root planning.

5. Surgery with citric acid treatment may be an advantage as compared to surgery alone. Osseous grafting in the defects may have limited, if any, additional effect.
6. Partial osseous resection in deep intraosseous defects for the purpose of reducing residual probing depth may not significantly affect the regenerative potential.
7. For clinical purposes it can be recommended: If a surgical procedure is to be performed in an area with an intraosseous defect, citric acid conditioning could be used in an attempt to enhance healing and partial osseous resection could be used to reduce residual probing depth.

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Paper I

Healing after treatment of periodontal intraosseous defects

I. Comparative study of clinical methods

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Abstract. Four clinical methods to evaluate healing after reconstructive therapy of intraosseous periodontal defects were compared: 1. probing attachment level, 2. probing bone level, 3. entry/re-entry bone height measurements, 4. radiographic bone height determinations. Thirteen patients with a total of 33 defects volunteered for the study.

It was found that the depth of the lesions recorded by the various methods showed differences which seem to relate to the varying nature of the methods. On the average, the periodontal probe penetrated 0.8 mm deeper during probing for bone level than during probing for attachment level and another 0.3 mm deeper after denudation of the lesions during entry/re-entry. The average gain of periodontal support following treatment was approximately 1.4 mm as recorded by probing attachment level, probing bone level and entry/re-entry bone height determinations, respectively. A high degree of correlation was found between all three probing methods when the changes following therapy for the individual sites were compared ($r=0.85, 0.75$ and 0.81 , respectively). Radiographic bone height showed lower degrees of correlation with all three probing parameters ($r=0.45, 0.46$ and 0.47 , respectively).

Evaluation of healing of periodontal tissues after therapeutic procedures is undoubtedly most accurately performed using biopsies of the treated tissue followed by microscopic analysis. Unfortunately, this technique can be used in humans only on rare occasions. Studies in humans have to rely upon clinical methods of evaluation despite their limitations to determine the precise nature of the healing response.

In several studies, measurements of the distance between a fixed point on the tooth and the base of the probable pocket (probing attachment level) have been used to evaluate healing (Ellegaard & Loe 1971, Ramfjord et al. 1975, Carraro et al. 1976, Yukna et al. 1976). In other studies the marginal alveolar bone has been probed under local anesthesia (probing bone level; Schallhorn et al. 1970, Dragoo & Sullivan 1973). Measurements from a fixed point on the

tooth to the alveolar bone during therapeutic surgery and then again during an exploratory re-entry procedure have been used in studies by Patur & Glickman (1962), Donnenfeld et al. (1970), Patur (1974), Froum et al. (1975a, b), Mellonig et al. (1976), Polson & Heijl (1978) and Sepe et al. (1978). Standardized radiographic techniques have been used to determine the bone level changes by Patur & Glickman (1962), Dragoo & Sullivan (1973) and Rosling et al. (1976).

Because of the inherent limitations of each of the clinical methods, several investigators have been evaluating their results using a combination of methods (Patur & Glickman 1962, Dragoo & Sullivan 1973, Rosling et al. 1976). This may or may not be necessary to obtain reliable information of the healing response.

The present study was undertaken in order to

compare four clinical methods of evaluating healing after therapeutic surgery of intraosseous periodontal defects: 1. probing attachment level, 2. probing bone level, 3. entry/re-entry bone height measurements, 4. radiographic bone height determinations. Knowledge regarding the relationship of these methods should determine whether it would be sufficient to use one of these methods only in future studies of periodontal healing, or if a combination of methods would be required to obtain adequate information of the healing response.

Material and Methods

Subjects and sites

The material of the present investigation was part of the material of a study evaluating the effect of reconstructive surgery on intraosseous periodontal lesions (Renvert & Egelberg 1981). Initially a total of 17 periodontally involved patients, 24–59 years of age, volunteered for the present methodological study. These patients had one or more teeth with proximal intraosseous defects, making a total of 41 sites available for the study. In four patients, the treatment had to be discontinued, leaving 13 subjects with 33 defects who completed the experiment.

Experimental and recording procedures

The experimental and recording procedures are outlined in Fig. 1. For the purpose of studying the reproducibility of the parameters, initial measurements of probing attachment level (PAL₀) and probing bone level (PBL₀) were performed by three independent examiners during one visit (A, B and C, authors S.R., A.B. & R.N.). The sequence of recording was alternated between the examiners. Radiographic examination was also carried out at this visit (R₀).

One week later examiner A made repeated determinations of probing attachment level (PAL₁) and probing bone level (PBL₁). Radio-

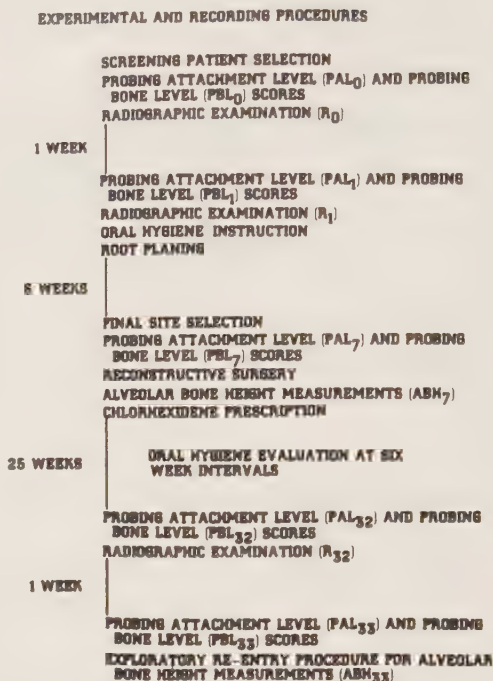


Fig. 1. Flow chart of experimental and recording procedures.

Schematische Beschreibung des Versuchsablaufes und der vorgenommenen Messungen.

Organigramme du plan de l'expérience.

graphic examination (R₁) was also performed again. The patients were then instructed in oral hygiene using a sequence of five weekly appointments. Root planing of the experimental sites was performed at the first two of these visits.

The experimental teeth were re-evaluated another six weeks later. Defects which at that time had probing pocket depth ≥ 6 mm from at least one aspect of the tooth were used for further study. Pre-operative probing attachment level (PAL₇) and probing bone level (PBL₇) measurements were taken by examiner A. Reconstructive periodontal surgery was carried out. The group of patients was treated by a total of four different operators.

Buccal and lingual mucoperiosteal flaps were raised to expose the intraosseous lesions. The

soft tissues were curetted from the defects and the root surfaces were carefully planed. The alveolar bone height of the defects was recorded by examiner A during surgery (ABH₇). No osseous recontouring was performed. In patients with two or more lesions, one or more of the lesions were treated by topical application of saturated citric acid to the instrumented root surfaces for 3 min. (The effect of citric acid conditioning will be presented in a subsequent report, Renvert & Egelberg 1981.) The flaps were replaced and sutured to obtain complete closure of the wounds. Twice daily rinses of 0.2% chlorhexidine (ICI, Macclesfield, Cheshire, UK) were used for 2–3 weeks following surgery. The patients were seen at 6-week intervals during the post-operative healing period to control and reinforce the performance of oral hygiene.

Thirty-two weeks after the start of the study the three examiners remeasured probing attachment level (PAL₃₂) and probing bone level (PBL₃₂). Radiographic examination was also performed (R₃₂). After another week repeated probing attachment level (PAL₃₃) and probing bone level (PBL₃₃) measurements were taken by examiner A. At this time an exploratory, re-entry surgical procedure was performed for the purpose of obtaining post-operative measurements of alveolar bone height (ABH₃₃).

Probing pocket depth and probing attachment level

Probing pocket depth and probing attachment level were measured as close as possible to 1 mm with a specially machined and calibrated probe (0.5 mm in diameter, 1 mm increments). Two measurements were taken from each of the defects, one from the buccal and one from the lingual aspect of the proximal surface. A metal onlay was used to provide reference points for the measurements. The positioning of the probe was guided by buccal and lingual steering grooves placed in the onlays. The steering grooves were placed in a way which directed the probe to the deepest portion of the pocket. The

distances from the pocket base to the gingival margin (probing pocket depth) and the edge of the onlay (probing attachment level) were recorded.

Probing bone level

Subsequent to the probing attachment level measurements, local anesthesia was given and probing bone level measurements were performed. These recordings were obtained using the onlays and the same steering grooves and the same probe as for the probing attachment level measurements. During probing, the probe was forced through the soft tissues towards the bone until definite resistance was met.

Entry/re-entry bone height

The bone level at the apical extent of the defects was determined after removal of soft tissues from the defects during reconstructive surgery and during the exploratory re-entry procedure. Measurements were again taken using the same buccal and lingual steering grooves of the onlays.

The level of the most coronal points of the buccal, lingual and proximal walls of the defects in relation to the edge of the onlay was also recorded. These figures were subtracted from the figures for the apical extent of the defects. In this way, the extent of the 3-wall, 3+2-wall and 3+2+1-wall components of the defects could be calculated. The figures give approximate representation of the defect components only. This is due to the fact that the angulation of the probe had to be varied to obtain the different measurements.

Radiographic bone height

Radiographs were obtained under standardized conditions using bite-block and film holders attached to the long cone of the X-ray apparatus (Figs. 2, 3). The bite-blocks were made in cold-curing acrylics and included a minimum of five teeth. The X-ray films were supported by the film holder as well as by the bite-block to avoid displacement and curving of the films.



Fig. 2. Film holder and bite-block.

Filmhalter und Beissblock.

Porte-film avec repère d'occlusion.

Attempts were made to place the films parallel to the long axis of the tooth to be examined. During exposure the extension arm of the film holder was inserted into an acrylic track mounted on the long cone of the X-ray apparatus. The system was arranged in a way that projected the X-rays perpendicularly to the long axis of the tooth. The exposures were made at 65 kV and 7.5 mA. The films were processed using a developing machine with standardized time for developing, fixing and rinsing.



Fig. 3. Film holder attached to the long cone of the X-ray apparatus.

Filmhalter, an den Langkonus des Röntgenapparates angeschlossen.

Porte-film rattaché au long cône de l'appareil radiographique.

All the measurements from the radiographs were made at the completion of the study. Pre- and post-operative films from all patients were coded, mounted and randomly projected for measurements using 10 X magnification. Tracings of the outline of the teeth, radiopaque restorations and the alveolar bone level of the intraosseous defects were made. Fixed reference points for measurements were selected; e.g. restoration margins, clearly identifiable cemento-enamel junctions or proximal contact points. The vertical distance from such reference points to the apical extent of the radiographic intraosseous defects was measured in mm. The apical extent of the defects was deemed to correspond to the point along the root surface where a periodontal ligament of even radiographic width could be observed.

The inherent errors of the radiographic measurements were evaluated by control measurements between clearly identifiable fixed reference points. Horizontal and vertical distances between such points located near the intraosseous defects were measured. Comparison of these measurements from pre- and post-operative radiographs was performed.

Statistical evaluation

The inter- and intra-examiner reproducibility of the measurements of probing attachment level and probing bone level was evaluated by comparison of the repeated pre- and post-operative recordings. Similarly, the intra-examiner reproducibility of the radiographic measurements was determined from the repeated examinations.

The effect of the reconstructive treatment was evaluated by comparing the pre-operative (7 weeks) and post-operative (33 weeks) recordings for each of the four clinical parameters used. Means of the buccal and lingual recordings of each proximal defect were used to describe the change following treatment of each defect. The relationship between the changes following treatment as expressed by the different parameters was studied using scatter dia-

Table 1. Deviation of single, repeated probing attachment level measurements. Percentage of concordant (0 mm) and discordant (± 1 , ± 2 , ± 3 mm) pre- and post-operative measurements. Comparison of recordings by examiners A, B and C obtained at the same visit and recordings by examiner A 1 week apart

Abweichungen einzelner, wiederholter Sondierungen des Epithelansatzniveaus. Prozentuales Vorkommen von übereinstimmenden (0 mm) und nicht übereinstimmenden (± 1 , ± 2 , ± 3 mm) Messungen vor und nach dem chirurgischen Eingriff. Die Vergleiche zwischen den Messergebnissen der Untersucher A, B und C wurden während der gleichen Sitzung vorgenommen, während die Vergleichswerte des Untersuchers A mit einer Woche zeitlicher Verschiebung erhalten wurden

Déviations entre plusieurs mesures de sondage d'un même niveau d'attache. Pourcentage de mesures concordantes (0 mm) et divergentes (± 1 , ± 2 , ± 3 mm) pré- et postopératoires. Comparaison des relevés obtenus par les examinateurs A, B et C au cours de la même visite et des relevés enregistrés par l'examineur A à une semaine d'intervalle

Pre-operative measurements

Deviation	Interexaminer comparisons			Intraexaminer comparisons
	A ₀ /B ₀ N=80	A ₀ /C ₀ N=79	B ₀ /C ₀ N=79	A ₀ /A ₁ N=79
0 mm	69	62	56	59
± 1 mm	31	33	39	35
± 2 mm	0	5	5	6

Post-operative measurements

Deviation	Interexaminer comparisons			Intraexaminer comparisons
	A ₃₂ /B ₃₂ N=64	A ₃₂ /C ₃₂ N=64	B ₃₂ /C ₃₂ N=64	A ₃₂ /A ₃₃ N=58
0 mm	59	52	58	55
± 1 mm	36	39	41	34
± 2 mm	5	9	1	9
± 3 mm	0	0	0	2

Pre-operative measurements (Messungen vor dem chirurgischen Eingriff, mesures préopératoires), interexaminer comparisons (Vergleiche zwischen den Untersuchenden, comparaisons inter-examineurs), intraexaminer comparisons (Vergleiche zwischen den Messungen eines Untersuchenden, comparaisons intra-examineur), deviation (Abweichung, déviation), post operative measurements (Messungen nach dem chirurgischen Eingriff, mesures postopératoires).

grams and calculations of coefficients of correlation. For these computations the recordings by examiner A were used.

Results

The reproducibility of the repeated measurements of probing attachment level and probing bone level is presented in Tables 1 and 2. Generally, around 60% of the repeated measurements were concordant, 35% showed a deviation of 1 mm and around 5% deviated 2 mm. The reproducibility of the probing bone level measurements seemed to be somewhat better than the probing attachment level scores.

Table 2. Deviations of single, repeated probing bone level measurements. Percentage of concordant (0 mm) and discordant (± 1 , ± 2 mm) pre- and post-operative measurements. Comparison of recordings by examiners A, B and C obtained at the same visit and recordings by examiner A 1 week later

Abweichungen einzelner, wiederholter Messungen des Knochenniveaus. Prozentuales Vorkommen von übereinstimmenden (0 mm) und voneinander abweichenden (± 1 , ± 2 mm) Messungen vor und nach dem chirurgischen Eingriff. Die Vergleiche zwischen den Messergebnissen der Untersucher A, B und C wurden während der gleichen Sitzung vorgenommen, während die Vergleichswerte des Untersuchers A mit einer Woche zeitlicher Verschiebung erhalten wurden

Déviations entre plusieurs mesures de sondage d'un même niveau osseux. Pourcentage de mesures pré- et postopératoires concordantes (0 mm) et divergentes (± 1 , ± 2 mm). Comparaison entre les données enregistrées par les examinateurs A, B et C au cours de la même visite et les relevés de l'examineur A une semaine plus tard

Pre-operative measurements

Deviation	Interexaminer comparisons			Intraexaminer comparisons
	A ₀ /B ₀ N=79	A ₀ /C ₀ N=78	B ₀ /C ₀ N=78	A ₀ /A ₁ N=77
0 mm	66	67	63	66
± 1 mm	33	31	36	34
± 2 mm	1	3	1	0

6 months post-operatively

Deviation	Interexaminer comparisons			Intraexaminer comparisons
	A ₃₂ /B ₃₂ N=64	A ₃₂ /C ₃₂ N=64	B ₃₂ /C ₃₂ N=64	A ₃₂ /A ₃₃ N=58
0 mm	63	68	68	63
± 1 mm	35	24	19	35
± 2 mm	2	8	13	2

Table 3. Reproducibility of radiographic measurements as evaluated from two repeated pre-operative examinations (R₀ & R₁) and one post-operative (R₃₂) examination. Measurements of defect depth (vertical distance between a coronal fixed reference point and apical extent of defect); horizontal control measurements (distance between two reference points in the same horizontal plane); and vertical control measurements (distance between two reference points in the same vertical plane). Means and standard deviations in mm

Wiederholbarkeit röntgenographischer Messungen, überprüft durch zwei Messungswiederholungen vor (R₀ & R₁) und eine nach dem chirurgischen Eingriff (R₃₂). Weiterhin werden die Resultate von Messungen der "Defekttiefe" (vertikaler Abstand zwischen einem koronalen Referenz-Festpunkt und der Defektausdehnung nach apikal hin); von horizontalen Messungen (Abstand zwischen zwei Referenzpunkten auf gleicher horizontaler Ebene); und von vertikalen Kontrollmessungen (Abstand zwischen zwei Referenzpunkten auf gleicher vertikaler Ebene) angegeben. Mittelwerte und Standarddeviationen in mm

Reproductibilité des mesures radiographiques évaluées lors de deux examens préopératoires (R₀ & R₁) et d'un examen post-opératoire (R₃₂). Mesures de la profondeur de la lésion (distance verticale entre un point coronaire fixe de référence et l'extrémité apicale de la lésion); mesures du contrôle horizontal (distance entre deux points de référence sur le même plan horizontal); et mesures du contrôle vertical (distance entre deux points de référence sur le même plan vertical). Moyennes et déviations standard exprimées en mm

	Initial defect depth (N=33)				Horizontal control measurements (N=33)				Vertical control measurements (N=33)			
	Linear distance		Difference between recordings		Linear distance		Difference between recordings		Linear distance		Difference between recordings	
	$\bar{x}$	$\pm$ s.d.	$\bar{x}$	$\pm$ s.d.	$\bar{x}$	$\pm$ s.d.	$\bar{x}$	$\pm$ s.d.	$\bar{x}$	$\pm$ s.d.	$\bar{x}$	$\pm$ s.d.
R ₀ /R ₁	12.8	3.6	-0.01	0.48	8.8	2.6	-0.02	0.08	10.7	7.0	0.00	0.31
R ₀ /R ₃₂			...				-0.02	0.17			0.01	0.34
R ₁ /R ₃₂			...				0.00	0.18			0.02	0.21

Initial defect depth (anfängliche Defekttiefe, profondeur initiale de la lésion), linear distance (linearer Abstand, distance linéaire), difference between recordings (Unterschied zwischen den Messungen, différence entre les données enregistrées), horizontal control measurements (horizontale Kontrollmessungen, mesures du contrôle horizontal), vertical control measurements (vertikale Kontrollmessungen, mesures du contrôle vertical).

The pre-operative scores for both methods appeared slightly more consistent than the post-operative scores.

Table 3 shows the results of the tests of the inherent error and the reproducibility of meas-

urements of the radiographic examinations. The standard deviations of repeated control measurements between fixed reference points in a horizontal plane were 0.08, 0.17 and 0.18 mm. Corresponding figures for the vertical control

Table 4. Probing pocket depth and depth of osseous defects of the 33 sites under study. Means $\pm$ s.d. of pre-operative/entry (7 weeks) and post-operative/re-entry (33 weeks) recordings

Sondierung der Taschentiefe und der Tiefe der knöchernen Defekte an 33 Regionen, während der Studie. Mittelwerte $\pm$ s.d. der präoperativen/Eingriffsmessungen (7 Wochen) und der postoperativen Messungen bei Eingriffswiederholungen (33 Wochen)

Profondeur de la poche au sondage et profondeur des lésions osseuses dans les 33 sites examinés. Moyennes $\pm$ s.d. des relevés entre les états préopératoires/opératoires (7 semaines) et postopératoires/d'évaluation (33 semaines)

	Probing pocket depth	Depth of osseous defect		
		3-wall component	3+2-wall component	3+2+1-wall component
Pre-operative/entry	7.7 $\pm$ 1.9	2.4 $\pm$ 1.5	4.2 $\pm$ 2.0	5.4 $\pm$ 1.7
Post-operative/re-entry	4.8 $\pm$ 1.7	1.3 $\pm$ 1.1	2.6 $\pm$ 1.6	3.4 $\pm$ 1.6

Probing pocket depth (Sondierung der Taschentiefe, sondage de la profondeur des poches), depth of osseous defect (Tiefe des knöchernen Defektes, profondeur de la lésion osseuse).

Table 5. Effect of reconstructive surgery in the 33 intraosseous defects under study. Gain of periodontal support in mm as expressed by probing attachment level, probing bone level, entry/re-entry bone height and radiographic bone height

Der Effekt rekonstruktiver Chirurgie bei den hier studierten 33 intraossösen Defekten. Der Gewinn an parodontaler Stütze in mm, ausgedrückt durch Sondierung des Attachmentniveaus, Sondierung des Knochenniveaus, Sondierung der Knochenhöhe bei chirurgischem Eingriff/Eingriffswiederholung und röntgenographisch gemessener Knochenhöhe

Résultat de la chirurgie reconstructive des 33 lésions infraosseuses examinées. Gain de support parodontal exprimé en mm, relevé au sondage du niveau d'attache, du niveau osseux, de la hauteur osseuse durant les interventions de traitement et d'évaluation et à la radiographie

	Probing attachment level N=33	Probing bone level N=33	Entry/ re-entry bone height N=32*	Radio- graphic bone height N=33
Mean	1.45	1.41	1.42	1.10
±s.d.	1.21	1.31	1.15	1.44

* One defect was not subjected to re-entry.

Probing attachment level (*Sondierung des Attachmentniveaus, sondage du niveau d'attache*), probing bone level (*Sondierung des Knochenniveaus, sondage du niveau osseux*), entry re-entry bone height (*Knochenhöhe bei chirurgischem Eingriff/Eingriffswiederholung, hauteur osseuse lors des interventions de traitement et d'évaluation*) + radiographic bone height (*röntgenographische Knochenhöhe, hauteur osseuse à la radiographie*).

measurements were 0.31, 0.34 and 0.21. The standard deviation of repeated determinations of the initial defect depth was 0.48 mm.

Pre- and post-operative probing pocket depths and depths of the intraosseous defects are given in Table 4. The probing pocket depth was reduced from an average of 7.7 to 4.8 mm following therapy. The osseous defects were also notably modified, although intraosseous components were still present 6 months post-operatively.

The effect of the reconstructive surgery in the 33 sites under study as recorded by the four parameters used is presented in Table 5. On the average, a gain of periodontal support amounting to around 1.4 mm was observed by probing attachment level, probing bone level and entry/re-entry bone height measurements. The radiographic bone height measurements demonstrated somewhat less average improvement: 1.1 mm.

The relationship between the recordings of the lesions by probing attachment level, probing bone level and entry/re-entry bone height determinations is presented in Table 6. On the average, the probing bone level measurements

were 0.8 mm deeper than the probing attachment level scores. The entry/re-entry bone height scores were another 0.3 mm deeper than the probing bone level figures. Similar patterns were seen for pre- and post-operative recordings.

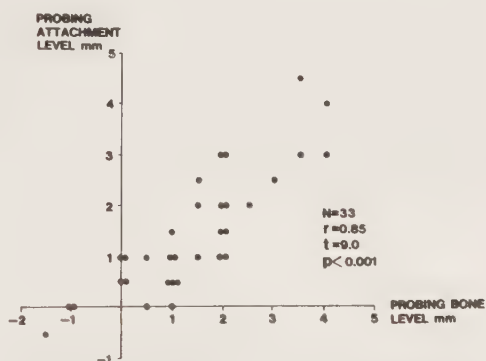


Fig. 4. Scatter diagram demonstrating the change following treatment recorded by probing attachment level and probing bone level measurements.

Streudiagramm über Veränderungen nach der Behandlung, gemessen durch Sondieren des Attachment- und Knochenniveaus.

Diagramme de dispersion indiquant après le traitement les nouvelles mesures obtenues par sondage du niveau d'attache et du niveau osseux.

Table 6. Comparison of the pre-operative and post-operative recordings of the lesions by probing attachment level, probing bone level and entry/re-entry bone height measurements. Percentage of concordant and discordant measurements and mean difference $\pm$ s.d. in mm

Vergleiche zwischen prä- und postoperativen Messungen der Läsionen durch Sondierung des Attachmentniveaus, Sondierung des Knochenniveaus und Messungen der Knochenhöhe beim chirurgischen Eingriff und der Eingriffswiederholung. Prozentuales Vorkommen übereinstimmender und nicht-übereinstimmender Messungen, sowie mittlere Differenz $\pm$ s.d. in mm

Comparaison des données pré- et postopératoires concernant les lésions, au sondage du niveau d'attache, du niveau osseux et en déterminant la hauteur osseuse durant les interventions de traitement et d'évaluation. Pourcentage de mesures concordantes et divergentes et différence moyenne $\pm$ s.d. en mm

	Probing bone level versus probing attachment level	Entry/re-entry bone height versus probing attachment level	Entry/re-entry bone height versus probing bone height
Pre-operative measurements	N=62	N=62	N=62
-1 mm	0	0	1
± 0 mm	34	21	73
+1 mm	55	56	23
+2 mm	10	18	3
+3 mm	1	5	0
Mean difference $\pm$ s.d.	+0.8 $\pm$ 0.7	+1.1 $\pm$ 0.8	+0.3 $\pm$ 0.5
Post-operative measurements	N=62	N=61	N=61
-2 mm	0	0	3
-1 mm	2	3	7
± 0 mm	34	21	51
+1 mm	43	36	31
+2 mm	21	35	8
+3 mm	0	5	0
Mean difference $\pm$ s.d.	+0.8 $\pm$ 0.8	+1.2 $\pm$ 0.9	+0.3 $\pm$ 0.9

Probing bone level versus probing attachment level (*Sondierung des Knochenniveaus, gegenüber Sondierung des Attachmentniveaus, comparaison entre le sondage du niveau osseux et le sondage du niveau d'attache*), entry/re-entry bone height versus probing attachment level (*Knochenhöhe bei chirurgischem Eingriff/Eingriffswiederholung, gegenüber Sondierung des Attachmentniveaus, comparaison entre la hauteur osseuse lors des interventions de traitement et d'évaluation et le niveau d'attache au sondage*), entry/re-entry bone height versus probing bone height (*Knochenhöhe bei chirurgischem Eingriff/Eingriffswiederholung, gegenüber Sondierung der Knochenhöhe, comparaison entre la hauteur osseuse lors des interventions de traitement et d'évaluation et la hauteur osseuse au sondage*).

The effect of reconstructive therapy as expressed by the various parameters is presented in the scatter diagrams of Figs. 4-9. Statistically highly significant correlations were observed between three of the methods: probing attachment level, probing bone level and entry/re-entry bone height determinations ($r=0.85$, 0.75 and 0.81 , respectively; $P<0.001$). Radiographic bone height showed a lower degree of correlation with each of the other methods of measure-

ments ($r=0.45$, 0.46 and 0.47 , respectively; $P<0.01$).

Discussion

This study set out to compare four currently used clinical methods for evaluating the healing response after reconstructive periodontal therapy. The design of the study included comparisons of the pre- and post-operative depths of the lesions recorded by the various parameters.

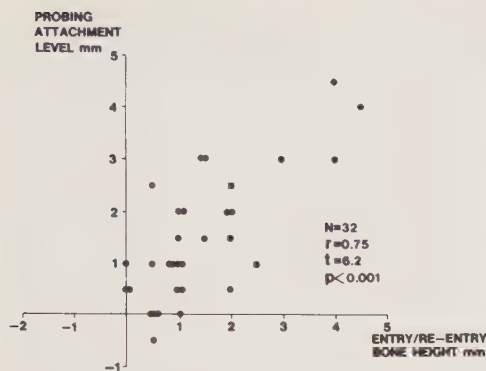


Fig. 5. Scatter diagram demonstrating the change following treatment recorded by probing attachment level and entry/re-entry bone height determinations.

Streudiagramm über Veränderungen nach der Behandlung, gemessen durch Sondieren der Attachmentniveaus und durch Bestimmungen der Knochenhöhe beim chirurgischen Eingriff und der Eingriffswiederholung.

Diagramme de dispersion démontrant le changement survenu après le traitement et mesuré par sondage du niveau d'attache et calcul de la hauteur osseuse durant les interventions de traitement et d'évaluation.

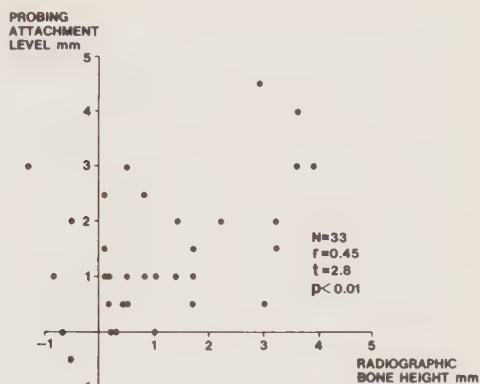


Fig. 7. Scatter diagram demonstrating the change following treatment recorded by probing attachment level and radiographic bone height determinations.

Streudiagramm über Veränderungen nach der Behandlung, gemessen durch Sondieren des Attachmentniveaus und der radiographischen Bestimmung der Knochenhöhe.

Diagramme de dispersion indiquant après le traitement les nouvelles mesures obtenues par sondage du niveau d'attache et radiographie de la hauteur osseuse.

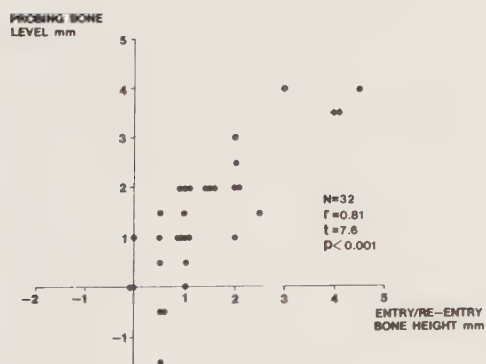


Fig. 6. Scatter diagram demonstrating the change following treatment recorded by probing bone level and entry/re-entry bone height determinations.

Streudiagramm über Veränderungen nach der Behandlung, gemessen durch Sondieren des Knochenlevels und der Bestimmung der Knochenhöhe beim chirurgischen Eingriff und der Eingriffswiederholung.

Diagramme de dispersion démontrant le changement survenu après le traitement et mesuré par sondage du niveau osseux et détermination de la hauteur osseuse durant les interventions de traitement et d'évaluation.

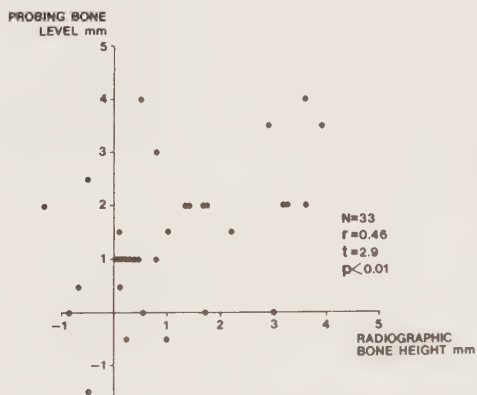


Fig. 8. Scatter diagram demonstrating the change following treatment recorded by probing bone level and radiographic bone height determinations.

Streudiagramm über Veränderungen nach der Behandlung, gemessen durch Sondieren des Knochenlevels und der radiographischen Bestimmung der Knochenhöhe.

Diagramme de dispersion indiquant après le traitement les nouvelles mesures obtenues au sondage du niveau osseux et à la radiographie de la hauteur osseuse.

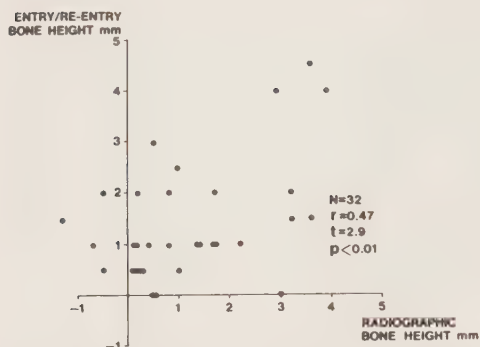


Fig. 9. Scatter diagram demonstrating the change following treatment recorded by entry/re-entry bone height and radiographic bone height determinations.

Streudiagramm über Veränderungen nach der Behandlung, gemessen durch Bestimmung der Knochenhöhe beim Eingriff und der Eingriffswiederholung, sowie durch röntgenographische Bestimmung.

Diagramme de dispersion indiquant les nouvelles mesures de la hauteur osseuse durant les interventions de traitement et d'évaluation ainsi qu'à la radiographie.

Also, the amounts of change of periodontal support following therapy assessed by the different parameters were compared. It was anticipated that analyses of the relationships between the methods would indicate whether the four methods are supplementary to each other and should all be used in future experimental studies, or, if one or more of the methods could conveniently be omitted.

On the average, the periodontal probe penetrated 0.8 mm deeper during probing for bone level than during probing for attachment level and another 0.3 mm deeper after denudation of the lesions. These differences seem to be congruous with available information on the extent of penetration of the probe tip in relation to the apical extent of the junctional epithelium (JE) and measurements of the distance from the apical end of the JE to the level of the alveolar bone. Several studies indicate that the probe tip will reach the apical end of the JE and may often penetrate a few tenths of a millimeter beyond the apical termination of the JE of nontreated specimens (Saglie et al. 1975, Listgarten et al.

1976, Sivertsson & Burgett 1976, Armitage et al. 1977, Spray et al. 1978, Robinson & Vitek 1979, van der Velden 1979). The distance between the apical end of the JE and the crest of alveolar bone was found to average about 1 mm by Stanley (1955) and Gargiulo et al. (1961). These histological data suggest that the probe tip during probing on the average will penetrate to a distance of 1 mm or slightly less from the bone. This distance corresponds to the clinical recordings obtained in the present study.

The average gain of periodontal support following treatment was approximately 1.4 mm as recorded by either probing attachment level, probing bone level or entry/re-entry bone height determinations. Also, a high degree of correlation was found between each of these three probing methods when the change following therapy for the individual sites was compared.

The close relationship between probing bone level measurements and entry/re-entry bone height determinations, in expressing the effect of treatment, indicates that both methods are equally useful to determine the height of the alveolar bone. Accordingly, re-entry procedures for the purpose of post-operative measurements may be omitted in future studies evaluating the effect of reconstructive periodontal therapy. The consistency of probing bone level measurements is in agreement with previous findings by Greenberg et al. (1976), who compared probing bone level recordings to measurements of the alveolar bone height of buccal aspects of human teeth during periodontal surgery. The mean differences of 0.3 mm between the two types of alveolar bone measurements observed in the present study may be explained by the fact that some measurements obtained after denudation of the lesions during the entry/re-entry procedures may have been taken to a slightly deeper portion of the defects.

The good correlation between changes of probing attachment level and probing bone level following treatment suggests that probing bone level measurements could also be omitted

in future therapeutic investigations. However, it may be valuable to use both parameters if there are reasons to believe that the therapy to be evaluated may affect regeneration of soft connective tissue and bone differently.

The magnitude of the standard deviation of the difference between measurements from repeated radiographic examinations of the preoperative lesions indicates that the radiographic method per se does not have an inferior reproducibility as compared to the clinical probing methods. However, the difficulties in assessing changes of alveolar bone height in radiographs are demonstrated by the weaker correlation between the radiographic determinations of the change following treatment and the changes recorded by each of the three probing parameters demonstrated. The fallacy of the use of radiographs has previously been pointed out by Friedman (1958), Theilade (1960), Prichard (1961), Suomi et al. (1968), Burnette (1971), Goldman & Stallard (1973) and in the review by Lang & Hill (1977).

The results of the present study indicate that probing attachment levels, possibly combined with probing bone levels, are the parameters of choice out of the presently available clinical examination methods for studies evaluating the effect of reconstructive periodontal therapy. Further improvement of the attachment level measurements may be accomplished by using a standardized probing force (van der Velden 1979).

The material of the present study included intraosseous defects treated with and without citric acid conditioning of the root surfaces. The coefficients of correlation between the various methods expressing the change following therapy were similar for acid- and nonacid-treated defects. Thus, the acid-treated and nonacid-treated lesions were pooled for the purpose of presentation of this methodological study. In a separate report it will be shown that acid-treated defects showed somewhat better regeneration than nonacid-treated lesions (Renvert & Egelberg 1981).

Zusammenfassung

Die Heilung nach der Behandlung intraossöser parodontaler Defekte.

I. Vergleichende Studie klinischer Methoden

Vier klinische Methoden zur Beurteilung der Heilung nach rekonstruktiver Behandlung intraossöser parodontaler Defekte wurden miteinander verglichen: 1. Das Sondieren des Epithelansatzniveaus. 2. Das Sondieren des Knochenniveaus. 3. Die Messung der Knochenhöhe bei chirurgischer Freilegung und bei chirurgischer Kontrollinspektion. 4. Die röntgenographische Bestimmung der Knochenhöhe. Für diese Studie stellten sich dreizehn Patienten mit zusammengekommen 33 Defekten freiwillig zur Verfügung.

Es wurde festgestellt, dass die mit den o.a. Methoden erhaltenen Messwerte der Tiefe parodontaler Läsionen, unterschiedlich ausfielen, was anscheinend den Methoden eigenen Verschiedenheiten angelastet werden muss. Im allgemeinen penetrierte beim Sondieren des Knochenniveaus die Parodontalsonde 0,8 mm tiefer als beim Sondieren des Epithelansatzniveaus und weitere 0,3 mm tiefer nach der Freilegung der Läsion während des chirurgischen Eingriffes und der chirurgischen Kontrollinspektion. Der durchschnittliche Gewinn an parodontaler Stütze belief sich auf etwa 1,4 mm, wie die Resultate des Sondierens des Epithelansatzes, des Knochenniveaus sowie der Bestimmung des Knochenniveaus bei chirurgischer Freilegung und chirurgischer Heilungsinspektion ergaben. Zwischen den drei Sondierungsmethoden wurde hochgradige Korrelation beobachtet, wenn die post-therapeutischen Veränderungen in den einzelnen Regionen miteinander verglichen wurden ($r=0,85, 0,75$ und $0,81$). Bei röntgenographisch ermittelter Knochenhöhe scheint im Vergleich mit den drei Sondierungsparametern geringere Korrelation vorzuliegen ($r=0,45, 0,46$ und $0,47$).

Résumé

Guérison après traitement de lésions parodontales infraosseuses.

I. Etude comparative de méthodes cliniques

Quatre méthodes cliniques d'évaluation de la guérison après une thérapeutique reconstructive de lésions parodontales infraosseuses ont été comparées:

1. Sondage du niveau d'attache. 2. Sondage du niveau osseux. 3. Mesures de la hauteur osseuse lors des interventions de traitement et d'évaluation. 4. Déterminations radiographiques du niveau osseux. Treize patients présentant un total de 33 lésions ont participé volontairement à cette étude.

On a constaté que la profondeur des lésions variait suivant la méthode employée. En général, la profondeur enregistrée par sondage du niveau osseux était de 0,8 mm supérieure à celle enregistrée par

sondage du niveau d'attache. Le sondage de la lésion après dénudation durant les interventions de traitement et d'évaluation indiquait une pénétration supplémentaire de 0,3 mm. Le gain moyen de support parodontal résultant du traitement était d'environ 1,4 mm lorsqu'il avait été enregistré par sondage du niveau d'attache ou du niveau osseux, ou par déterminations de la hauteur osseuse lors des interventions de traitement et d'évaluation. La comparaison des changements obtenus dans les sites individuels après la thérapeutique a révélé une étroite corrélation entre ces trois méthodes de sondage ($r=0,85, 0,75$ et $0,81$ respectivement). La hauteur osseuse à la radiographie indiquait une moindre corrélation avec les trois paramètres de sondage ($r=0,45, 0,46$ et $0,47$ respectivement).

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Paper II

Healing after treatment of periodontal intraosseous defects

II. Effect of citric acid conditioning of the root surface

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Abstract. Citric acid conditioning of the root surface as a supplement to replaced flap surgery of intraosseous periodontal defects was evaluated. Thirteen patients and a total of 45 proximal defects with residual probing pocket depth ≥ 6 mm after initial preparation were used. The effect of treatment was studied in matched subsamples of the total material including one acid-treated and one nonacid-treated defect from each subject. The results demonstrated that an average gain of probing attachment level amounting to 2.0 mm was obtained following acid treatment as compared to 1.1-1.2 mm for the nonacid-treated controls. Corresponding figures for gain of probing bone level were 1.2-1.3 mm for acid treatment and 0.8-0.9 mm for controls. The clinical significance of these findings was discussed.

Regeneration after surgical procedures in periodontal intraosseous defects has been reported by several authors. For example, Ellegaard & L  e (1971) obtained "complete regeneration" in 72% of teeth with 3-wall defects, in 40% of teeth with combined 3- and 2-wall lesions and in 45% of those with 2-wall lesions. Rosling et al. (1976) studied 2- and 3-wall intrabony defects and obtained a mean gain of probing attachment level of 3.5 mm and a gain of radiographic bone support of 2.8 mm. Polson & Heijl (1978) reported a mean amount of bone apposition of 2.5 mm after treatment of different types of intraosseous defects.

The question of whether the regeneration of the defects observed clinically involves formation of new connective tissue attachment to the teeth has been addressed in some recent studies utilizing block biopsies and microscopic examination (Caton & Zander 1976, Hiatt et al. 1978, Moskow et al. 1979, Listgarten & Rosenberg 1979). The results of these studies suggest that an epithelial lining may persist post-operatively along the root surface adjacent to the newly

formed bone. Thus, new attachment may not occur or may be of only limited extent following the use of conventional regenerative periodontal surgery.

Studies by Register (1973) and Register & Burdick (1975, 1976) in cats and dogs suggested an accelerated healing and new cementum formation of surgically detached periodontal tissues after citric acid conditioning of the denuded dentin surface as compared to nonacid-treated controls. This finding was confirmed in a recent electron microscopic study by Ririe et al. (1980). Topical citric acid application resulted in demineralization of the dentin surface and uncovering of collagen fibrils of the dentin matrix. Interdigitation between the exposed collagen fibrils and the newly formed collagen of the wound was observed at an early stage during healing. It was suggested that this phenomenon may be the cause of the enhanced healing following acid treatment as compared to the controls.

The effect of citric acid conditioning on healing after surgical debridement has also been

Table 1A. Pre- and post-operative records for the total material of 26 acid-treated defects. Data for individual defects, means and standard deviations. *=data not available

*Prä- und postoperative Messungen des Gesamtmateriales bestehend aus 26 mit Säure behandelten Defekten. Daten der individuellen Defekte, Mittelwerte und Standarddeviationen. *=keine Daten verfügbar*

*Données pré- et postopératoires pour l'ensemble des 26 lésions traitées à l'acide. Données pour les lésions individuelles, moyennes et déviations standard. *=données indisponibles*

Subject	Tooth and proximal Surface	Age of subject (years)	Pre-op. probing pocket depth (mm)	No. of tooth surfaces involved	Defect circumference (degrees)	No. of osseous walls of defect	Depth of 3+2+ wall components of defect (mm)
1	45d	60	8.5	3	300	2	7
1	33m	60	9	1	90	2	6.5
2	43m	42	11	3	210	2	8
2	23m	42	7.5	1	60	1	3
3	47d	32	7	3	120	3	5
3	46d	32	11	3	180	3	7
3	32m	32	11	4	300	3	8
4	25m	32	11	4	300	1	7
4	46m	32	11	2	120	3	8
5	13d	35	7.5	2	180	1	3.5
5	35d	35	4.5	1	120	1	4
5	35m	35	5.5	2	150	2	4
6	36m	55	8.5	2	120	2	6
6	15m	55	6	1	90	3	6
7	35m	57	10.5	3	180	2	9
8	46d	41	8	2	120	3	7.5
9	45d	48	6	3	300	3	4
9	33d	48	7	2	180	3	5
10	21m	72	6	2	90	2	4
10	43m	72	6	1	60	2	4
11	34d	27	6	2	120	3	3
11	35d	27	6.5	2	120	3	3
11	45d	27	6.5	2	120	3	5
11	44d	27	6.5	2	120	3	3
12	46m	70	6	1	90	3	3
13	45d	25	6.5	2	120	3	2
Mean		45.85	7.71	2.15	152.31	2.39	5.21
±s.d.		15.84	2.05	0.88	73.93	0.75	2.01

Tooth and proximal surface *Zahn und Approximaloberfläche, dent et surface proximale*, Age of subject (years) *Alter des Probanden (Jahre), âge du sujet (années)*, Pre-op. probing pocket depth (mm) *Präoperative Sondierung der Taschentiefe (mm), sondage préopératoire de la profondeur de la poche (mm)*, Number of osseous walls of defect *Anzahl knöcherner Wände des Defektes, nombre de parois de la lésion osseuse*, post-op. local site plaque score (percent) *Postoperative Region, Plaque Score (Beurteilungseinheit) in Prozent, score postopératoire de plaque sur le site local (pourcent)*, gain of probing attachment level (mm) *Gewinn an sondiertem Attachmentniveau (mm), sondage du gain de niveau d'attache (mm)*, Gain of probing bone level (mm) *Gewinn an sondiertem Knocheniveau (mm), sondage du gain de niveau osseux (mm)*, Residual probing depth (mm) *Sondierungstiefe (mm) der Residualtasche, sondage de la profondeur de la poche résiduelle*.

evaluated in experimentally induced, through-and-through furcation pockets in dogs (Crigger et al. 1978, Nilvéus et al. 1980). New connective tissue attachment and complete closure of the furcation defects was obtained in the majority

of acid-treated specimens as opposed to the nonacid-treated controls which all became re-epithelialized. Recent results from human experimentation corroborate these results in dogs. Cole et al. (1980) demonstrated new connective

Depth of 3+2-wall components of defect (mm)	Depth of 3-wall component of defect (mm)	Post-op. full-mouth plaque score (%)	Post-op. local site plaque score (%)	Gain of probing attachment level (mm)	Gain of probing bone level (mm)	Residual probing depth (mm)
6	2	1.8	12.5	0	-0.5	4.5
2	0	1.8	0	2.5	1.5	4
6	0	*	*	5.5	4	4
2	1	*	*	1.5	1	5
3.5	3	8.9	50	2	1.5	4.5
7	7	8.9	12.5	3	2	6.5
7	2	8.9	0	3	3.5	6.5
6.5	4	26.5	87.5	2	2	8
8	3	26.5	50	4	4	5
2	0	4	0	3	2	2.5
3	1	4	0	2	2	2
4	4	4	16.7	2	2.5	3
6	5	9.8	37.5	4.5	3.5	3
3	1.5	9.8	12.5	1	2	3
8	2	9.9	12.5	2.5	3	7
6	3	11.6	37.5	0.5	0	6
2	1	5	0	0	1	6
2.5	2	5	0	0	0.5	7.5
*	*	30.4	25	2	0	3
*	*	30.4	25	3	0	2
2	1.5	11.2	12.5	2	0	3
1	1	11.2	12.5	2	0	3
3	2	11.2	0	2	1	3
2	1.5	11.2	25	2	0.5	3
2.5	1	12	0	1	-0.5	4
1.5	0	1.2	0	2.5	2	3
4.02	2.02	11.03	17.88	2.14	1.48	4.31
2.28	1.70	9.00	21.75	1.32	1.38	1.76

tissue attachment in all of 10 biopsies obtained from periodontally compromised human teeth which had been subjected to periodontal flap surgery and acid conditioning. In contrast to this finding, Steiner et al. (1981) failed to obtain new attachment in all of seven similar, nonacid-treated specimens. It thus appears that acid conditioning may facilitate the achievement of new attachment following periodontal surgery.

In a pilot study, Cole et al. (1981) used clinical parameters and evaluated the effect of citric

acid conditioning of the root surfaces during periodontal surgery. Teeth with residual probing pocket depth ≥ 5 mm following initial oral hygiene instruction and root planing were used for the study. Contralateral areas were randomly selected for full thickness, replaced flap procedure with or without topical citric acid application. Six months post-operatively, reduced probing pocket depth and gain of probing attachment level was observed. A mean probing attachment level gain for acid-treated

Table 1B. Pre- and post-operative records for the total material of 19 nonacid-treated defects

*Prä- und postoperative Messungen des Gesamtmaterials, bestehend aus 19 nicht mit Säure behandelten Defekten**Données pré- et postopératoires pour l'ensemble des 19 lésions non traitées à l'acide*

Subject	Tooth and proximal surface	Age of subject (years)	Pre-op. probing pocket depth (mm)	No. of tooth surfaces involved	Defect circumference (degrees)	No. of osseous walls of defect	Depth of 3+2+1-wall components of defect (mm)
1	43d	60	9	1	90	1	4
2	33m	42	6	1	90	1	2
3	44m	32	8	1	90	3	7
4	34d	32	7	1	90	3	4
4	44d	32	8.5	2	180	3	5.5
5	24d	35	5	2	120	2	4
6	35m	55	5.5	2	90	2	3.5
7	35d	57	6	3	180	2	6
7	11m	57	5	2	90	2	2
8	35d	41	6	3	270	3	5
9	35m	48	8.5	3	180	3	5.5
9	35d	48	8.5	3	180	3	5
10	43d	72	9	1	60	2	3
10	11m	72	7	3	180	2	5
11	36d	27	9.5	1	90	3	5
11	23d	27	9.5	2	120	2	5
11	13m	27	8	1	90	3	1.5
12	43m	70	9	1	90	3	5
13	33m	25	8	1	90	1	2
Mean		45.85	7.53	1.79	124.74	2.32	4.21
±s.d.		15.84	1.53	0.86	54.10	0.75	1.53

surfaces of 2.1 mm was obtained as compared to 1.5 mm for the nonacid-treated control surfaces.

In the present study the use of citric acid conditioning of the instrumented root surfaces during periodontal surgery was further evaluated. Healing of acid-treated and nonacid-treated intraosseous periodontal defects was compared using clinical methods of evaluation.

Material and Methods

Thirteen periodontally involved patients 25–72 years of age volunteered for the study. A total of 45 intraosseous defects with the fundus of the lesions located at proximal tooth surfaces were treated (26 experimental and 19 control sites). Oral hygiene instruction and root planing were initially performed during a 2-month period. Each patient who participated in the study had a minimum of two separate areas

with radiographic evidence of intraosseous lesions and with a residual probing pocket depth ≥ 6 mm after the initial preparation.

Parameters

Pre-operative measurements of probing pocket depth, probing attachment level and probing bone level were obtained using methods described earlier (Renvert et al. 1981a).

During surgery, measurements were taken from fixed reference points to the crests of the alveolar bone and to the fundus of the defects. The depths of the 3-wall, 3+2-wall and 3+2+1-wall components of the defects were calculated (Renvert et al. 1981a). The number of osseous walls of the defects and the number of tooth surfaces involved were recorded. The circumferential dimension of the defects was estimated and recorded as 30° increments of the total 360° circumference.

Depth of 3+2-wall components of defect (mm)	Depth of 3-wall component of defect (mm)	Post-op. full. mouth plaque score (%)	Post-op. local site plaque score (%)	Gain of probing attachment level (mm)	Gain of probing bone level (mm)	Residual probing depth (mm)
2.5	1	1.8	0	1.5	1	5
1	0	*	*	0.5	1	4.5
6	4	8.9	12.5	1	1.5	7
3	1.5	26.5	75	1	1	4.5
4	2	26.5	50	1.5	2	4.5
3	1	4	0	0.5	1	3
3	2	9.8	37.5	1.5	2	3.5
4	2	9.9	12.5	3	4	4
1.5	1	9.9	33.3	1	2	3.5
4.5	4	11.6	50	0.5	1	3.5
5	3	5	0	-0.5	-1.5	8.5
5	5	5	0	0	-0.5	6
*	*	30.4	37.5	1	-1	5
*	*	30.4	50	1	1	3
3.5	2	11.2	0	2.5	0.5	4.5
3	0	11.2	0	2.5	1	5
1	1	11.2	37.5	1.5	0	4.5
2	1	12	25	1	0.5	6
1	1	1.2	0	2.5	0	3.5
3.12	1.85	11.03	23.38	1.24	0.87	4.68
1.52	1.41	9.00	23.71	0.90	1.22	1.41

Presence or absence of plaque after erythrosin application was recorded for all surfaces of the mouth at 6-week intervals during the post-operative 6-month period. A percentage full-mouth plaque score was calculated for each interval and a mean of all four post-operative scores was then computed (post-operative full-mouth plaque score). Similarly, a mean post-operative, experimental site percentage score was calculated from the plaque records of the buccal and oral aspects of the proximal surface at the site of the osseous defect.

Experimental procedures

The surgical intervention included sulcular incisions followed by reflection of full thickness mucoperiosteal flaps. Granulomatous tissue was removed and the osseous walls of the defects were exposed. The roots were carefully planed. No osseous recontouring or attempt at

cortical fenestration of the defect walls was made.

A minimum of one defect in each subject was used as nonacid-treated control. One or more defects were treated by a 3-min topical application of saturated citric acid (pH 1) carried on cotton pledgets. Pledgets darkening during the application period due to incomplete hemostasis were replaced. The areas were profusely irrigated with water or saline during 1 min following the acid conditioning procedure. The flaps were carefully adapted to allow complete coverage of the interdental area and closed with interrupted silk sutures. Four different operators performed the surgeries. All measurements were taken by one individual (S. R.).

Chlorhexidine (Hibitane®, ICI, Macclesfield, UK) was prescribed for twice daily 0.2% rinses, to supplement the oral hygiene procedures during the first 2 - 3 post-operative

weeks. One week after discontinuation of chlorhexidine and again 3 weeks later the patients were seen for oral hygiene reinstruction and polishing of the teeth. Subsequently, the patients were seen every 6 weeks for recording of

plaque scores, oral hygiene reinstruction and tooth cleaning. No attempts at deep scaling or soft tissue curettage of the experimental sites were made at these appointments. Six months after surgery, final measurements of probing

Table 2. Results of analysis of regression between various defect characteristics for the total material of 45 acid-treated and control defects and the healing response as evidenced by gain of probing attachment level, gain of probing bone level and residual probing depth. Coefficient of correlation and level of statistical significance

Resultate der Regressionsanalyse zwischen verschiedenen Defektcharakteristika des Gesamtmaterials von 45 mit Säure behandelten und Kontrolldefekten und der Heilungsantwort, so wie sie durch den Gewinn an sondiertem Attachmentniveau, Gewinn an sondiertem Knochenniveau und Residualtaschentiefen veranschaulicht wird. Korrelationskoeffizient und Niveau statistischer Signifikanz

Résultats de l'analyse de la régression entre différentes caractéristiques des lésions pour un matériel total de 45 lésions traitées et non traitées à l'acide et le degré de guérison mesuré par sondage du gain du niveau d'attache, du gain du niveau osseux et de la profondeur résiduelle de la poche. Coefficient de corrélation et niveau de signification statistique

Defect characteristic	Coefficient of correlation		
	Gain of probing attachment level	Gain of probing bone level	Residual probing depth
Age of patient	-0.20	-0.17	-0.02
Pre-operative probing	N.S.	N.S.	N.S.
pocket depth	0.39	0.23	0.61
No. of tooth surfaces involved	$P < 0.01$	N.S.	$P < 0.001$
	0.07	0.30	0.35
	N.S.	$P < 0.05$	$P < 0.05$
Defect circumference	-0.07	0.23	0.37
Number of osseous walls of defect	N.S.	N.S.	$P < 0.05$
Depth of 3+2+1-wall components of defect	-0.19	-0.15	0.21
Depth of 3+2-wall components of defect	N.S.	N.S.	N.S.
Depth of 3-wall component of defect	0.27	0.46	0.48
Post-operative full-mouth plaque score	N.S.	$P < 0.01$	$P < 0.01$
Post-operative experimental site plaque score	0.27*	0.43*	0.49
	N.S.	$P < 0.01$	$P < 0.01$
	-0.02*	0.08*	0.37
	N.S.	N.S.	$P < 0.05$
	-0.04°	0.13°	-0.04°
	N.S.	N.S.	N.S.
	0.04°	0.15°	0.05°
	N.S.	N.S.	N.S.

* N = 41

° N = 42

Coefficient of correlation *Korrelationskoeffizient, coefficient de corrélation*, Gain of probing attachment-level *Gewinn an sondiertem Attachmentniveau, sondage du gain de niveau d'attache*, Number of tooth surfaces involved *Anzahl betroffener Zahnoberflächen, nombre de surfaces dentaires impliquées*, Defect circumference *Defektfumfang, circonférence de la lésion*, Depth of 3+2+1-wall components of defect *Tiefe der 3+2+1-Wanddefekt-komponenten, profondeur des lésions présentant des combinaisons de 3+2+1-parois*, Post-operative full mouth plaque score *Postoperative Plaquescore (Beurteilungseinheit) des gesamten Mundes, score postopératoire de plaque pour toute la bouche*, Post-operative experimental site plaque score *Postoperative Plaquescore (Beurteilungseinheit) der Experimentalregion, score postopératoire de plaque au site expérimental*.

pocket depth, probing attachment level and probing bone level were carried out.

Results

The data from the total material of 26 acid-treated and 19 nonacid-treated defects are presented in Tables 1A and 1B. A comparison between the two groups shows that the means of some of the pre-operative characteristics of the defects were somewhat different (e.g. depths of 3+2+1-wall and 3+2-wall components of defect). It was considered uncertain to what extent these variations might invalidate a statistical comparison between the two treatment procedures. Analyses of regression were therefore performed to study the relationships between the various characteristics of the defects and the healing response as evidenced by the amounts of gain of probing attachment level, probing bone level and the residual probing depth following treatment. The results of these analyses are presented in Table 2.

Statistically significant correlation was observed between gain of probing attachment level and pre-operative probing pocket depth ($r = 0.39$, $P < 0.01$). Also, significant correlations were found between gain of probing bone level and pre-operative depths of 3+2+1-wall and 3+2-wall components of defects as well as the number of tooth surfaces involved ($r = 0.46$, $P < 0.01$, $r = 0.43$, $P < 0.01$ and $r = 0.30$, $P < 0.05$, respectively). The 6-month residual probing depth showed significant correlations to pre-operative probing pocket depth, depths of 3+2-wall, 3+2+1-wall and 3-wall components of defects as well as defect circumference and number of tooth surfaces involved ($r = 0.61$, $P < 0.001$, $r = 0.49$, $P < 0.01$, $r = 0.48$, $P < 0.01$, $r = 0.37$, $P < 0.05$, $r = 0.37$, $P < 0.05$ and $r = 0.35$, $P < 0.05$, respectively). All other defect characteristics as well as age of patient and mean post-operative plaque scores showed insignificant relationships with the results of therapy.

Subsamples of acid-treated and nonacid-treated defects were drawn based upon the above analyses. Tables 3A and 3B include one

acid-treated and one nonacid-treated defect from each subject selected in an attempt to obtain the best possible matching of pairs of defects within each subject with respect to pre-operative probing pocket depth. Tables 4A and 4B include defects selected for matching with primary respect to pre-operative depth of 3+2-wall and 3+2+1-wall components of defects and with secondary consideration to depth of 3-wall component of defect, defect circumference and number of tooth surfaces involved. This latter procedure necessitated the exclusion of one subject to obtain adequate matching (subject 7).

Tables 3 and 4 demonstrate that an average gain of probing attachment level amounting to 2.0 mm was obtained following acid treatment as compared to 1.1–1.2 mm for the nonacid-treated controls. The differences between the two treatment procedures were statistically significant (Wilcoxon matched-pairs signed-ranks sum test for small samples: Table 3A vs 3B $P < 0.05$; Table 4A vs 4B $P < 0.05$; Student's *t*-test for paired samples: Table 3A vs 3B $P < 0.01$; Table 4A vs 4B $P < 0.02$). The gain of probing bone level was 1.2–1.3 mm for acid treatment and 0.8–0.9 mm for controls. These differences were not statistically significant. Similarly, no significant differences were observed between the two groups with respect to residual probing depth.

Table 5 presents the proportion of defects listed in Tables 3 and 4 showing gain of probing levels amounting to 2 mm or more. More acid-treated defects demonstrated ≥ 2 mm gain of probing attachment level than the nonacid-treated controls (Table 3A vs 3B: $\chi^2 = 7.72$, $P < 0.01$; Table 4A vs 4B: $\chi^2 = 6.17$, $P < 0.02$). No significant difference between the two treatment procedures could be observed with respect to probing bone level.

Discussion

Significant problems of methodology and design are inherent in studies of the effect of

Table 3A Pre- and post-operative records for the subsample of 13 acid-treated defects selected for matching pairs of acid and nonacid-treated defects with primary respect to pre-operative probing pocket depth

Prä- und postoperativ registrierte Daten einer Untergruppe von 13 mit Säure behandelten Defekten bei vergleichbaren Paaren für mit Säure behandelte und nicht mit Säure behandelte Defekte; bei besonderer Berücksichtigung präoperativer Taschensondierungstiefen

Subject	Tooth and proximal surface	Age of subject (years)	Pre-op. probing pocket depth (mm)	No. of tooth surfaces involved	Defect circumference (degrees)	No. of osseous walls of defect	Depth of 3+2+1-wall components of defect (mm)
1	33m	60	9	1	90	2	6.5
2	23m	42	7.5	1	60	1	3
3	47d	32	7	3	120	3	5
4	25m	32	11	4	300	1	7
5	35d	35	4.5	1	120	1	4
6	36m	55	8.5	2	120	2	6
7	35m	57	10.5	3	180	2	9
8	46d	41	8	2	120	3	7.5
9	45d	48	6	3	300	3	4
10	43m	72	6	1	60	2	4
11	35d	27	6.5	2	120	3	3
12	46m	70	6	1	90	3	3
13	45d	25	6.5	2	120	3	2
Mean		45.85	7.46	2.00	138.46	2.23	4.92
±s.d.		15.84	1.89	1.00	77.98	0.83	2.11

Table 3B. Pre- and post-operative records for the subsample of 13 nonacid-treated defects selected for matching pairs of acid and non acid-treated defects with primary respect to pre-operative probing pocket depth

Prä- und postoperativ registrierte Daten einer Untergruppe von 13 nicht mit Säure behandelten Defekten bei vergleichbaren Paaren für mit Säure behandelte und nicht mit Säure behandelte Defekte; bei besonderer Berücksichtigung präoperativer Taschensondierungstiefen

Subject	Tooth and proximal surface	Age of subject (years)	Pre-op. probing pocket depth (mm)	No. of tooth surfaces involved	Defect circumference (degrees)	No. of osseous walls of defect	Depth of 3+2+1-wall components of defect (mm)
1	43d	60	9	1	90	1	4
2	33m	42	6	1	90	1	2
3	44m	32	8	1	90	3	7
4	44d	32	8.5	2	180	3	5.5
5	24d	35	5	2	120	2	4
6	35m	55	5.5	2	90	2	3.5
7	35d	57	6	3	180	2	6
8	35d	41	6	3	270	3	5
9	35m	48	8.5	3	180	3	5.5
10	43d	72	9	1	60	2	3
11	13m	27	8	1	90	3	1.5
12	43m	70	9	1	90	3	5
13	33m	25	8	1	90	1	2
Mean		45.85	7.42	1.69	124.62	2.23	4.15
±s.d.		15.85	1.48	0.86	59.81	0.83	1.70

Données pré- et postopératoires sur le sous-échantillon composé de 13 lésions traitées à l'acide choisies pour la comparaison entre les paires de lésions traitées et non traitées à l'acide, une attention particulière ayant été consacrée à la profondeur des poches avant l'intervention

Depth of 3+2-wall components of defect (mm)	Depth of 3-wall component of defect (mm)	Post-op. full-mouth plaque score (%)	Post-op. local site plaque score (%)	Gain of probing attachment level (mm)	Gain of probing bone level (mm)	Residual probing depth (mm)
2	0	1.8	0	2.5	1.5	4
2	1	*	*	1.5	1	5
3.5	3	8.9	50	2	1.5	4.5
6.5	4	26.5	87.5	2	2	8
3	1	4	0	2	2	2
6	5	9.8	37.5	4.5	3.5	3
8	2	9.9	12.5	2.5	3	7
6	3	11.6	37.5	0.5	0	6
2	1	5	0	0	1	6
*	*	30.4	25	3	0	2
1	1	11.2	12.5	2	0	3
2.5	1	12	0	1	-0.5	4
1.5	0	1.2	0	2.5	2	3
3.67	1.83	11.03	21.88	2.00	1.31	4.42
2.33	1.59	9.00	27.24	1.14	1.22	1.89

Données pré- et postopératoires sur le sous-échantillon composé de 13 lésions non traitées à l'acide choisies pour la comparaison entre les paires de lésions traitées et non traitées à l'acide, une attention particulière ayant été consacrée à la profondeur des poches avant l'intervention

Depth of 3+2-wall components of defect (mm)	Depth of 3-wall component of defect (mm)	Post-op. full-mouth plaque score (%)	Post-op. local site plaque score (%)	Gain of probing attachment level (mm)	Gain of probing bone level (mm)	Residual probing depth (mm)
2.5	1	1.8	0	1.5	1	5
1	0	*	*	0.5	1	4.5
6	4	8.9	12.5	1	1.5	7
4	2	26.5	50	1.5	2	4.5
3	1	4	0	0.5	1	3
3	2	9.8	37.5	1.5	2	3.5
4	2	9.9	12.5	3	4	4
4.5	4	11.6	50	0.5	1	3.5
5	3	5	0	-0.5	-1.5	8.5
*	*	30.4	37.5	1	-1	5
1	1	11.2	37.5	1.5	0	4.5
2	1	12	25	1	0.5	6
1	1	1.2	0	2.5	0	3.5
3.08	1.83	11.03	21.88	1.19	0.89	4.81
1.66	1.27	9.00	20.03	0.90	1.40	1.56

Table 4A. Pre- and post-operative records for the subsample of 12 acid-treated defects selected for matching pairs of acid- and nonacid-treated defects with primary respect to depths of 3+2-wall and 3+2+1-wall components of defect and with secondary consideration to depth of 3-wall component of defect, defect circumference and number of tooth surfaces involved. This procedure necessitated the exclusion of one subject to obtain adequate matching (subject 7)

Prä- und postoperativ registrierte Daten einer Untergruppe von 12 mit Säure behandelten Defekten bei vergleichbaren Paaren von mit Säure und nicht mit Säure behandelten Defekten; bei besonderer Berücksichtigung von 3+2-Wand- und 3+2+1-Wanddefektkomponenten und mit weiterer Berücksichtigung der Tiefe von 3-

Subject	Tooth and proximal surface	Age of subject (years)	Pre-op. probing pocket depth (mm)	No. of tooth surfaces involved	Defect circumference (degrees)	No. of osseous walls of defect	Depth of 3+2+1-wall components of defect (mm)
1	33m	60	9	1	90	2	6.5
2	23m	42	7.5	1	60	1	3
3	47d	32	7	3	120	3	5
4	25m	32	11	4	300	1	7
5	13d	35	7.5	2	180	1	3.5
6	36m	55	8.5	2	120	2	6
8	46d	41	8	2	120	3	7.5
9	45d	48	6	3	300	3	4
10	21m	72	6	2	90	2	4
11	35d	27	6.5	2	120	3	3
12	46m	70	6	1	90	3	3
13	45d	25	6.5	2	120	3	2
Mean		44.92	7.46	2.08	142.50	2.25	4.54
±s.d.		16.17	1.50	0.90	78.99	0.87	1.82

Table 4B. Pre- and post-operative records for the subsample of 12 nonacid-treated defects selected for matching pairs of acid and nonacid-treated defects with primary respect to depths of 3+2-wall and 3+2+1-wall components of defect and with secondary consideration to depth of 3-wall component of defect, defect circumference and number of tooth surfaces involved. This procedure necessitated the exclusion of one subject to obtain adequate matching (subject 7)

Prä- und postoperativ registrierte Daten einer Untergruppe von 12 nicht mit Säure behandelten Defekten bei vergleichbaren Paaren von mit Säure und nicht mit Säure behandelten Defekten; bei besonderer Berücksichtigung von 3+2-Wand- und 3+2+1-Wanddefektkomponenten und bei weiterer Berücksichtigung der Tiefe der 3-

Subject	Tooth and proximal surface	Age of subject (years)	Pre-op. probing pocket depth (mm)	No. of tooth surfaces involved	Defect circumference (degrees)	No. of osseous walls of defect	Depth of 3+2+1-wall components of defect (mm)
1	43d	60	9	1	90	1	4
2	33m	42	6	1	90	1	2
3	44m	32	8	1	90	3	7
4	44d	32	8.5	2	180	3	5.5
5	24d	35	5	2	120	2	4
6	35m	55	5.5	2	90	2	3.5
8	35d	41	6	3	270	3	5
9	35m	48	8.5	3	180	3	5.5
10	11m	72	7	3	180	2	5
11	36d	27	9.5	1	90	3	5
12	43m	70	9	1	90	3	5
13	33m	25	8	1	90	1	2
Mean		44.92	7.50	1.75	130.00	2.25	4.46
±s.d.		16.17	1.54	0.87	59.08	0.87	1.45

Wandkomponenten des Defektes, des Defektumfangs und der Anzahl der betroffenen Zahnoberflächen. Ein Proband musste ausgeschlossen werden um korrekte Vergleichbarkeit zu erhalten (Proband 7)

Données pré- et postopératoires sur le sous-échantillon constitué de 12 lésions traitées à l'acide, sélectionnées pour la comparaison entre les paires de lésions traitées et non traitées à l'acide, une attention primordiale ayant été consacrée aux profondeurs de lésions à 3+2- et 3+2+1-parois, et une attention secondaire à la profondeur de lésions à 3-parois, à la circonférence des lésions et au nombre de surfaces dentaires intéressées. Ce processus a entraîné l'exclusion d'un sujet afin d'obtenir un assortiment adéquat (sujet 7)

Depth of 3+2-wall components defect (mm)	Depth of 3-wall component of defect (mm)	Post-op. full-mouth plaque score (%)	Post-op. local site plaque score (%)	Gain of probing attachment level (mm)	Gain of probing bone level (mm)	Residual probing depth (mm)
2	0	1.8	0	2.5	1.5	4
2	1	*	*	1.5	1	5
3.5	3	8.9	50	2	1.5	4.5
6.5	4	26.5	87.5	2	2	8
2	0	4	0	3	2	2.5
6	5	9.8	37.5	4.5	3.5	3
6	3	11.6	37.5	0.5	0	6
2	1	5	0	0	1	6
*	*	30.4	25	2	0	3
1	1	11.2	12.5	2	0	3
2.5	1	12	0	1	-0.5	4
1.5	0	1.2	0	2.5	2	3
3.18	1.73	11.13	22.73	1.96	1.17	4.33
2.02	1.74	9.43	28.41	1.18	1.16	1.66

Wandkomponenten des Defektes, des Defektumfangs und der Anzahl der betroffenen Zahnoberflächen. Ein Proband musste ausgeschlossen werden um korrekte Vergleichbarkeit zu erhalten (Proband 7)

Données pré- et postopératoires sur le sous-échantillon constitué de 12 lésions non traitées à l'acide, sélectionnées pour la comparaison entre les paires de lésions traitées et non traitées à l'acide, une attention primordiale ayant été consacrée aux profondeurs de la lésion à 3+2- et 3+2+1-parois, et une attention secondaire à la profondeur de la lésion à 3-parois, à la circonférence de la lésion et au nombre de surfaces dentaires impliquées. Ce processus a entraîné l'exclusion d'un sujet afin d'obtenir un assortiment adéquat (sujet 7)

Depth of 3+2-wall components defect (mm)	Depth of 3-wall component of defect (mm)	Post-op. full-mouth plaque score (%)	Post-op. local site plaque score (%)	Gain of probing attachment level (mm)	Gain of probing bone level (mm)	Residual probing depth (mm)
2.5	1	1.8	0	1.5	1	5
1	0	*	*	0.5	1	4.5
6	4	8.9	12.5	1	1.5	7
4	2	26.5	50	1.5	2	4.5
3	1	4	0	0.5	1	3
3	2	9.8	37.5	1.5	2	3.5
4.5	4	11.6	50	0.5	1	3.5
5	3	5	0	-0.5	-1.5	8.5
*	*	30.4	50	1	1	3
3.5	2	11.2	0	2.5	0.5	4.5
2	1	12	25	1	0.5	6
1	1	1.2	0	2.5	0	3.5
3.32	1.91	11.13	20.46	1.13	0.83	4.71
1.59	1.30	9.43	22.55	0.86	0.94	1.70

Table 5. Proportion of acid-treated and nonacid-treated defects listed in Tables 3 and 4 demonstrating gain of probing attachment level and gain of probing bone level amounting to 2 mm or more

Das Verhältnis zwischen den in den Tabellen 3 und 4 angegebenen, mit Säure und nicht mit Säure behandelten Defekten. Diese Tabelle veranschaulicht den Gewinn an sondiertem Attachmentniveau und an sondiertem Knochenniveau von 2 mm und mehr

Proportion de lésions traitées et non traitées à l'acide énumérées aux tableaux 3 et 4 indiquant le gain des niveaux d'attache et osseux mesurés à la sonde, s'élevant à 2,0 mm ou plus

	No. of defects Probing attachment level	Probing bone level
<i>Defects from Tables 3A and 3B</i>		
Acid-treated (N=13)	9	5
Control (N=13)	2	3
<i>Defects from Tables 4A and 4B</i>		
Acid-treated (N=12)	8	4
Control (N=12)	2	2

Number of defects *Anzahl der Defekte, nombre de lésions*, Probing attachment level *sondiertes Attachmentniveau, sondage du niveau d'attache*, Probing bone level *sondiertes Knochenniveau, sondage du niveau osseux*, Defects from Tables 3A and 3B *in den Tabellen 3A und 3B angegebene Defekte*, *lésions des Tableaux 3A et 3B*, Acid-treated *Defekte, mit Säure behandelt*, *traité à l'acide*, Control *Kontrolle, contrôle*.

different therapeutic procedures on intraosseous periodontal defects. One of the problems is that contralateral, true "mirror-image" defects in the same patients are rarely available to allow a split-mouth design. In the present study an attempt to overcome this problem was made. The relative importance of various defect characteristics for the outcome of the treatment was analyzed. Matching and selection of subsamples of the material were then performed considering the importance of the different defect characteristics. This procedure may reduce the chances of making erroneous interpretations in studies of the present nature. However, it will not eliminate the problem. It may well be that other and unknown defect characteristics than those analyzed are of significant importance.

Another problem relates to the possible im-

portance of minor variations in surgical techniques and differences in experience and skills of the operator. Four different operators were used in the present study. The number of defects treated by three of them were too small for a meaningful comparison between the results of the different operators. Attempts at analysis of the significance of inter-operator variability will be made in a subsequent study (Renvert et (1981).

The limitations of probing measurements to assess the effect of therapy are apparent. Probing attachment level determinations do not give any insight into the histological nature of a gain of attachment. Probing bone level measurements may be reliable to assess the level of the alveolar bone (Greenberg et al. 1976, Renvert et al 1981a). However, the clinical significance and longevity of a gain of the alveolar bone level may be limited if this gain is associated with re-epithelization of the defect.

In spite of the above limitations, therapeutic problems of periodontal intraosseous defects warrant attention and research. Pressure-sensitive periodontal probes have recently become available on the market (Polson et al. 1980). Such probes may improve the precision of the probing measurement and should be evaluated in future studies.

The present study demonstrates that acid conditioning of the root surface resulted in a gain of probing attachment level which in statistical terms was significantly higher than the gain for nonacid-treated controls. The gain of probing bone level was not statistically significant between the two groups. The slight improvement of healing following acid treatment is in accord with the results of Cole et al. (1981).

The clinical significance, however, of the difference between acid-treated and nonacid-treated defects is limited. The magnitude of the mean differences of probing attachment level (0.8–0.9 mm) should be viewed in relation to the reliability of the probing method. Renvert et al. (1981a) found that approximately one-third of

repeated probe measurements deviated 1 mm. For clinical evaluation purposes it may be more meaningful to analyze the material with respect to the frequency of defects which demonstrated a gain of probing level which could hardly be explained by measurement errors. According to the findings by Renvert et al. (1981a), a gain of probing levels amounting to 2 mm would satisfy this criterion. Analysis of the subsamples of the present study indicates that 2 mm gain of probing attachment level was obtained more frequently following acid conditioning as compared to nonacid-treated controls.

It will rest upon the individual clinician to evaluate if citric acid conditioning should be introduced as a supplement to other procedures during reconstructive periodontal surgery. The combined findings of available animal experimentation and clinical studies in humans in relation to possible side effects of the acid application need to be considered. So far, the present authors and their collaborators have not observed any side effects (e.g. flap necrosis, root sensitivity) provided the application procedure is made with care and under good visual control.

The average gain of probing attachment and probing bone levels of the present study, irrespective of the use of acid application, was less than what has been reported by Carraro et al. (1976), Froum et al. (1976), Rosling et al. (1976) and Polson & Heijl (1978) following conventional replaced flap surgery. There seems to be no apparent explanation to this discrepancy. However, factors such as patient and site selection, methods of evaluation, amount of pre-operative therapy, variations in surgical techniques and post-operative care may be of importance. The results of regression analyses of the present study indicate that variations in post-operative plaque control may not be crucial. However, the post-operative plaque scores indicate that the level of plaque control of most of the participants was not optimal. Only a few of the defect sites may have been kept plaque free throughout the 6-month post-operative

period. With extreme emphasis on plaque control (Rosling et al. 1976) and continuously plaque-free teeth, improved healing may have been accomplished.

Several sites demonstrated a residual probing depth of 5 mm or more 6 months post-operatively. Smaller residual probing depths would have been more desirable after the surgical interventions. The analyses of regression showed that deep residual probing depth was positively related to the depth of the pre-operative defect. This observation raises the question about the performance of partial osseous resection of the defect walls combined with apical positioning of the flaps during surgery. It is possible that partial resection can be performed without significant compromise of the attachment levels of adjacent tooth surfaces. Partial resection may or may not decrease the potentials for regeneration and may result in a shallower post-operative probing depth. Future studies ought to be carried out to elucidate this problem.

Zusammenfassung

Die Heilung nach der Behandlung intraossöser Defekte. II. Erfolg der Behandlung der Wurzeloberfläche mit Zitronensäure

Die vorliegende Studie befasst sich mit der Behandlung von Wurzeloberflächen mit Zitronensäure als Zusatzbehandlung zur Lappenoperation intraossöser parodontaler Defekte. Als Probanden wurden dreizehn Patienten mit zusammen 45 approximalen Defekten ausgewählt, bei denen eine Sondierungstiefe der Residualtaschen von ≥ 6 mm nach initialer Behandlung konstatiert worden war. Der Behandlungserfolg wurde in 4 vergleichbaren Untergruppen des Gesamtmateriales studiert, einschliesslich eines mit Säure behandelten und eines nicht mit Säure behandelten Defektes bei jedem einzelnen Probanden. Die Resultate zeigten, dass ein durchschnittlicher Gewinn bis zu 2,0 mm beim Sondieren des Attachmentniveaus nach der Säurebehandlung konstatiert wurde. Im Vergleich wurde 1,1 – 1,2 mm Gewinn bei den nicht mit Säure behandelten Kontrollzähnen gemessen. Die entsprechenden Werte für den Gewinn an sondiertem Knochenniveau waren 1,2 – 1,3 mm für mit Säure behandelte und 0,8 – 0,9 mm für Kontrollzähne. Die klinische Bedeutung dieser Ergebnisse wird diskutiert.

Résumé

Guérison après traitement de lésions parodontales infraosseuses.

II. Effet de l'acide citrique conditionnant la surface radiculaire

On a testé le traitement d'appoint constitué par l'utilisation d'acide citrique pour conditionner la surface radiculaire lors d'opérations de lésions parodontales infraosseuses par repositionnement à lambeau.

L'expérience a porté sur 13 patients présentant un total de 45 lésions proximales avec des poches résiduelles ≥ 6 mm après préparation initiale. L'effet du traitement a été étudié par comparaison de sous-échantillons provenant de l'ensemble du matériel et comprenant une lésion traitée à l'acide et une lésion non traitée à l'acide par sujet. Les résultats ont indiqué un gain moyen d'attache de 2,0 mm après traitement à l'acide et de 1,1 – 1,2 mm dans les échantillons témoins non traités à l'acide. Parallèlement, les sondages indiquaient des gains de niveau osseux de 1,2 – 1,3 mm lors du traitement à l'acide et de 0,8 – 0,9 mm dans les échantillons témoins. La signification clinique de ces observations a été discutée.

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Paper III

HEALING AFTER TREATMENT OF PERIODONTAL INTRAOSSEOUS DEFECTS

III. Effect of osseous grafting and citric acid conditioning

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Running head: Healing of intraosseous defects

Key words: Periodontal healing - citric acid -
osseous grafts

ABSTRACT

The present study was performed to find out if the healing of periodontal intraosseous defects could be improved through the combined use of citric acid conditioning of the root surfaces and grafting of autogenous intraoral cancellous bone. 28 proximal defects in 19 patients were treated surgically including acid conditioning of the root surfaces. Another 25 defects in these patients were treated with acid conditioning combined with osseous grafts using the maxillary tuberosity areas as donor sites.

Both therapies, e.g. citric acid conditioning alone and acid conditioning combined with osseous grafting resulted in approximately 1 mm gains of probing attachment and probing bone levels. Within the parameters of this study osseous grafting did not enhance the effect of citric acid conditioning alone. Limited improvement of the treated defects of the present study was obtained in spite of the use of supplementary regenerative techniques.

INTRODUCTION

Osseous grafts have been introduced to enhance regeneration following treatment of intraosseous periodontal defects. Reports on grafts of autogenous intraoral cancellous bone; autogenous as well as allogenic iliac cancellous bone and marrow, and lyophilized allogenic cortical bone have been published (Shallhorn et al. 1970, Shallhorn & Hiatt 1972, Dragoo & Sullivan 1973, Hiatt & Schallhorn 1973, Patur 1974, Mellonig et al. 1976, Sepe et al. 1978). These reports demonstrate successful healing following the use of each of these graft materials.

Studies where grafted lesions have been compared to non-grafted control sites have been reported by Carraro et al. (1976), Froum et al. (1976), Altieri et al. (1979), Pearson et al. (1981) and Movin & Borring-Møller (1982). The results of these studies are not conclusive but it appears that there may be some advantage to the use of osseous grafts over periodontal flap surgery alone.

Citric acid conditioning of the root surfaces has also been introduced to enhance regeneration after periodontal surgery. Findings in humans by Cole et al. (1980), Cole et al. (1981), Renvert & Egelberg (1981), Steiner et al. (1981), Albair et al. (1982) and Common & McFall (1983) demonstrate some improvement following the use of citric acid compared to non-acid treated control sites.

The present study was undertaken to find out if the healing of periodontal intraosseous defects following citric acid conditioning could be further improved through the combined use of acid conditioning and osseous grafts.

MATERIAL AND METHODS

Subjects

19 periodontally involved patients, 26 to 66 years of age, volunteered for the study. Initial therapy consisting of oral hygiene instruction and root planing of the experimental sites was performed a minimum of two months prior to final patient and site selection. Patients that demonstrated a full mouth plaque score less than 15% (see Plaque Scores below) and at least two separate proximal sites with radiographic intraosseous lesions combined with a residual probing pocket depth ≥ 6 mm were included in the study. Defects adjacent to teeth with root furrows, root concavities or furcation apertures were not included in the study. A total of 53 defects were treated (28 acid treated and 25 acid treated and grafted). Radiographs of some of the selected defects are shown in Fig. 1.

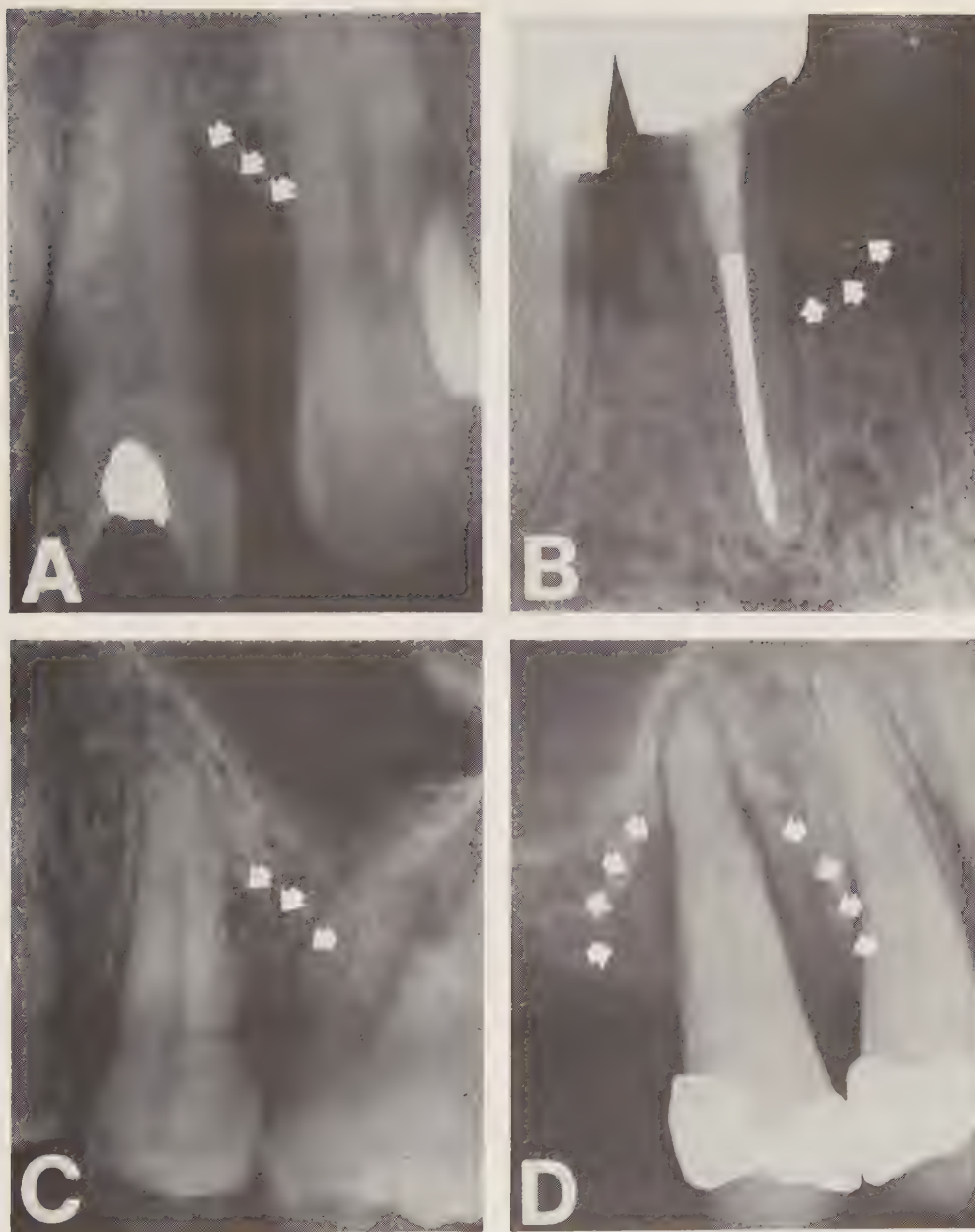


Fig.1. Radiographs of a selection of defects of different depths prior to surgery.

- A. A shallow defect, depth 1.75 mm (Subject 15, site 22D).
- B. A medium defect, depth 3.5 mm (Subject 17, site 45M). (Root fillings were present in 1 of the 53 treated teeth).
- C. A medium defect, depth 4.0 mm (Subject 12, site 25D).
- D. A deep defect, 6.5 mm (Subject 6, site 15D).

Clinical parameters

The following parameters were recorded:

- 1) plaque scores
- 2) bleeding upon probing
- 3) probing pocket depth
- 4) probing attachment level
- 5) probing bone level
- 6) osseous defect circumference
- 7) number of tooth surfaces involved
- 8) number of osseous walls of the defects
- 9) depth of 3+2+1-, 3+2- and 3-wall components of the osseous defect
- 10) postoperative soft tissue crater depth.

Probing pocket depths, probing attachment levels and probing bone levels were determined immediately preoperatively as well as at the final examination 12 months postoperatively. Records of the various osseous defect characteristics were taken during the surgical procedure. Plaque scores and bleeding upon probing were recorded at the 6- and 12-months postoperative appointments. Postoperative soft tissue crater depths were measured at 1, 2 and 3 weeks postoperatively. All measurements throughout the study were made by the same examiner.

Plaque scores: Six aspects of each tooth were examined: mesio-buccal, mid-buccal, disto-buccal, mesio-lingual, mid-lingual and disto-lingual. Plaque was disclosed with an erythrosine dye (Trace[®], Lorvic Corporation, St. Louis, MO, U.S.A.). Areas adjacent to the gingival margin which exhibited a deep stain that could easily be removed with the side of a probe were scored as having plaque. Plaque scores were expressed as the percentage of total surfaces under evaluation which revealed the presence of plaque. Two types of plaque scores were calculated: 1) full mouth plaque scores, based upon the six aspects of all teeth in the mouth, 2) local site plaque scores, based upon the buccal and lingual aspects of the proximal surface involved by the defect. Mean postoperative full mouth and mean postoperative local site plaque scores were averages calculated from the recordings at the 6- and 12-months postoperative examinations.

Bleeding upon probing: Bleeding upon probing was determined with the same probe as above using a standardized probing force of 0.50 N and recorded immediately prior to the probing pocket depth measurements. Full mouth and local site bleeding scores were calculated in the same manner as plaque scores.

Probing pocket depth and probing attachment level: Measurements of probing pocket depth and probing attachment level were made using an electronic pressure sensitive probe (Electronic Periodontal Probe, Model 200, Vine Valley Research, Middlesex, N.Y., U.S.A.). A specially machined probe tip having 1 mm increments and 0.5 mm diameter was used. Each site was probed using a standardized force of 0.75 N. Recordings to the nearest 0.5 mm were made from the buccal and lingual aspects of the proximal defect sites. A vacuum-adapted soft acrylic onlay (Scheu-Dental, Iserlohn, West Germany) was used to provide reference points for the probing measurements (Froum et al. 1975, Badersten et al. 1984). The placement of the probe was guided by the interdental indentations of the thin onlay and the probe was directed apically toward the deepest point on the mid-proximal aspect of the root surface. Probing pocket depth was measured from the gingival margin to the tip of the probe. Probing attachment level was recorded from the onlay margin to the tip of the probe. Means of the buccal and lingual recordings for each proximal defect were used to evaluate the effect of treatment.

Probing bone level: Immediately after probing pocket depth and probing attachment level measurements were completed, probing bone level measurements were taken under local anesthesia using a similar probe tip. During probing, the probe was directed apically toward the mid-proximal aspect of the root surface and forced through the soft tissue toward the bone until definite resistance was met. The probing bone level was recorded as the distance from the onlay margin to the probe tip. Means of buccal and lingual recordings were calculated.

Osseous defect circumference, number of tooth surfaces involved and number of osseous walls of the defects: These characteristics were recorded after debridement of the surgical sites. The circumference of the osseous defect in relation to the root circumference was estimated to the nearest 30° at the coronal portion of the defect. The number of tooth surfaces involved at the apical portion of the defect was recorded as 1

if the defect was localized to the proximal tooth surface only, as 2 when the defect also encompassed the buccal or lingual surface, and as 3 when proximal, buccal and lingual surfaces were involved. The number of osseous walls of the defects was recorded as 1 when only a proximal wall was present, as 2 if the proximal defect had a buccal or lingual wall, and as 3 when both buccal and lingual walls were present.

Depth of 3+2+1-, 3+2- and 3-wall components of the osseous defect: The osseous defect depth was recorded using the onlay margins as reference points for a series of measurements. The distance to the most apical extent of the proximal defect was measured from both buccal and lingual onlay margin. The crest of the buccal wall of the defect was measured from the buccal onlay margin. The crest of the lingual wall of the defect was measured from the lingual onlay margin. The crest of the proximal wall of the defect was measured from the buccal onlay margin.

The height of the buccal wall was calculated by subtracting its crest level measurement from the buccal measurement of the apical extent of the osseous defect. Similarly, the lingual wall height was calculated from the corresponding lingual measurements. To calculate the height of the proximal wall, its crest measurement was subtracted from the average of the buccal and lingual measurements of the apical extent of the defect. In this way, the depths of the defects could be expressed relative to the number of walls of the defects. Consequently the depths were calculated for the 3-wall, 3+2-wall and the 3+2+1-wall components of the defects. The figures give only approximate representation of the defect components due to the fact that angulation of the probe had to be varied to obtain the different measurements.

Postoperative soft tissue crater depth: The depths of interdental soft tissue craters were measured from the buccal aspect. The distance from the onlay margin to the most apical point of the crater was first measured. Then, the distance from the onlay margin to the most coronal extent of the buccal crater wall was recorded. The crater depth was calculated by subtracting the buccal wall measurement from the apical point measurement. A mean of the 1-, 2- and 3-week recordings was calculated. Again, the computed depths are approximate crater depths due to the difference in probe angulation for the two readings. The measurements were taken using a minimum of force to avoid compression of the soft tissues and interference with the healing process.

Treatment procedures

Buccal and lingual mucoperiosteal flaps were raised to expose the intra-osseous lesion. Granulomatous tissue was removed and the osseous walls of the defect were uncovered. Following hemostasis, the root surfaces were carefully planed and treated by a 3-minute topical application of saturated citric acid using cotton pledgets, followed by thorough irrigation with water. Osseous recontouring was not performed. The flaps were replaced and sutured to obtain complete closure of the wounds.

At least one defect in each subject was used for osseous grafting. The maxillary tuberosity areas were used as donor sites. Full thickness flaps were reflected for access in these areas and pieces of bone were removed with a rongeur. The bone material was prepared for grafting by removal of the cortical layer and by cutting the material into small pieces.

Three different operators were used, treating 6, 6 and 7 patients respectively. Individual variations in surgical techniques were allowed such as the use of sulcular or inversed bevel incisions, bur penetration of the defect walls, variations in size of the grafted pieces and force during packing, use of surgical dressing and the use of postoperative systemic antibiotics.

Chlorhexidine (Hibitan[®], ICI, Macclesfield, Great Britain) was prescribed for twice daily, 0,2% rinses to supplement the oral hygiene procedures during the first two postoperative weeks. Sutures and dressings (if used) were removed one week after surgery. The patients were seen at weekly intervals during the first three postoperative weeks and then again another three weeks later (six weeks postoperatively) for oral hygiene reinstruction and polishing of the teeth. Subsequently, the patients were seen every six weeks for oral hygiene reevaluation and rubber cup polishing of the teeth. No attempts at deep scaling or soft tissue curettage of the experimental sites were made at these appointments.

RESULTS

The pre- and postoperative records for the acid treated and acid treated and grafted defects are presented in Tables 1A and 1B and in Fig.2.

Table 1 A. Pre- and postoperative records for the 28 acid treated defects. Data for individual defects, means and standard deviations.

Sub- ject	Site	Preop probing pocket depth (mm)	Number of tooth surfaces involved	Defect circum- ference (degrees)	Number of osseous walls of defect	Depth of 3+2+1 wall components (mm)	Depth of 3+2-wall components (mm)	Depth of 3-wall component (mm)
1	14 D	6	2	120	2	2.5	1.75	1
2	14 D	7.25	1	90	2	3.5	2	0.5
3	43 M	6	1	90	3	2	1	1
	45 D	6.5	2	120	3	2	1.5	0
4	24 M	6	1	90	3	3.5	2	1.5
	14 M	5.75	2	120	3	4	3.5	2.5
5	21 M	6.75	1	90	2	2.5	1	0.5
	43 M	6.25	2	90	3	4.5	3.5	3
6	11 M	6.5	2	120	2	4	2.5	2
	15 M	6	2	120	2	3	3	2.5
7	15 D	5.75	1	90	3	2.5	2.5	2
8	41 M	5	1	90	2	4	1	0.5
	33 M	5	1	90	3	4.25	4	1.5
9	36 M	5.75	1	90	3	3	2	1.5
10	44 D	5.5	*	*	*	2.75	2.5	0
11	46 M	6	1	90	3	3	2.5	1
	43 M	9	1	90	3	5	2	1
12	21 M	6	1	90	2	*	*	*
13	33 D	6	1	90	3	3.5	3.5	2
14	24 D	6.25	1	90	3	2	1.75	1.5
15	22 D	5.5	1	90	3	1.75	1.5	1.5
	24 D	5.5	1	90	2	4	3.75	2
16	21 M	5.5	*	*	*	2	2	1.5
17	14 M	6.25	2	120	3	3	3	2
	45 M	5.75	1	90	3	3.5	3	2.5
18	13 D	7	1	90	3	2	1.75	1.5
	12 M	7	1	90	2	4	3.25	0.5
19	11 M	5.5	1	90	3	2.75	2	1.5
Mean		6.1	1.3	97.0	2.7	3.1	2.4	1.4
S.D.		0.8	0.5	12.9	0.5	0.9	0.9	0.8
N=		28	26	26	26	27	27	27

*Data not available

Postop soft tissue crater depth (mm)	Postop full mouth plaque score (%)	Postop local site plaque score (%)	Postop full mouth bleeding score (%)	Postop local site bleeding score (%)	Change of probing attachment level (mm)	Change of probing bone level (mm)	Residual probing depth (mm)
2.1	4.4	50	12.4	25	1	0.5	4.25
2.0	10.5	25	13.5	50	2.75	3.25	3.5
0.3	8.5	0	7.5	0	1.75	0.25	3.75
2.0	8.5	0	7.5	0	2	2	4.75
3.1	1.5	50	5.5	0	1.25	-0.25	3.25
2.4	1.5	25	5.5	0	0.25	0.5	4.5
2.3	3.5	0	4	25	0.75	-0.5	4.5
3.6	3.5	0	4	25	1.25	2	3.5
2.5	28.2	75	16	25	0	0.75	4.25
3.3	28.2	25	16	25	-1.25	0	5.5
*	2	0	7.4	25	0	-0.5	5.75
1.9	12	0	14.6	25	0.75	0.5	3
2.1	12	0	14.6	0	-0.25	0.75	4.75
1.8	14	0	8	50	2.25	0.25	3
3.3	13	0	19	0	0.75	1	3
2.7	16.5	0	15.5	50	2	0.25	5
5.0	16.5	75	15.5	50	1.25	0.25	5
1.6	32.4	0	15.3	50	0.75	1.25	4.75
1.3	4	0	5	50	2.25	1.5	3
*	17.3	0	19	50	0.75	0.25	5.5
*	20.4	50	12.9	0	1.25	1.25	4.75
*	20.4	25	12.9	50	1	2.25	3.75
*	25	25	19.6	25	1.25	0.75	4
*	52.7	75	20.3	25	0.75	-0.25	4.75
*	52.7	75	20.3	25	0.75	1	4
*	14.8	0	8.8	0	1	0.75	4.75
*	14.8	0	8.8	0	1.5	1.25	4.25
*	19.2	75	8	25	2	1.5	3.5
2.4	15.8	23.2	12.2	24.1	1.1	0.8	4.2
1.0	12.6	29.6	5.3	19.8	0.9	0.9	0.8
18	19	28	19	28	28	28	28

Table 1 B. Pre- and postoperative records for the 25 acid treated and bone grafted defects. Data for individual defects, means and standard deviations.

Sub- ject	Site	Preop probing pocket depth (mm)	Number of tooth surfaces involved	Defect circum- ference (degrees)	Number of osseous walls of defect	Depth of 3+2+1- wall components (mm)	Depth of 3+2-wall components (mm)	Depth of 3-wall component (mm)
1	24 D	6	2	120	2	3.75	2.5	1
2	23 M	6.5	1	90	2	4	4	1
3	25 D	5.75	1	90	2	5	1.5	0
4	24 D	5.75	1	90	3	3	2.5	2
	15 M	7	3	270	3	4.5	3.25	2.5
	35 M	7.25	2	150	2	6.5	4	2
5	24 D	6.75	2	90	3	2.5	2	1.5
	34 D	7	3	210	3	3.5	2.25	2
6	15 D	6.25	2	120	2	6.5	6	5
7	11 M	7	1	90	3	4.5	2	1.25
8	44 D	5.75	1	90	3	3	3	2.75
9	46 M	5.75	1	90	3	2.5	2.5	0.5
10	33 M	5.5	1	90	3	4.25	3	1.5
11	33 M	6	1	90	2	3.5	2	0
12	25 D	6	1	90	3	4	2	1
	23 D	5.5	1	90	2	2	0.5	0
13	35 M	6	1	90	1	3	1	0
14	25 D	6.5	1	90	3	3	2.5	2
15	43 M	5	*	*	2	3.5	3	0
16	46 M	7	*	*	*	5.5	3.25	2.5
17	36 M	8	2	120	3	4.5	4	2.75
	46 M	5.75	1	90	3	3	2.5	1.5
18	34 D	7	1	90	2	3.25	1.5	0
	12 D	5.5	1	90	3	3.75	2	1
19	45 M	6	2	120	3	4.5	2.25	2
Mean		6.3	1.4	110.9	2.5	3.9	2.6	1.4
S.D.		0.7	0.7	44.7	0.6	1.1	1.1	1.2
N=		25	23	23	24	25	25	25

*Data not available

Postop soft tissue crater depth (mm)	Postop full mouth plaque score (%)	Postop local site plaque score (%)	Postop full mouth bleeding score (%)	Postop local site bleeding score (%)	Change of probing attachment level (mm)	Change of probing bone level (mm)	Residual probing depth (mm)
1.4	4.4	0	12.4	25	1.75	0.75	4.25
1.5	10.5	25	13.5	50	2	3	4.25
*	8.5	25	7.5	25	0.25	0.25	5
2.9	1.5	50	5.5	0	0.5	1.75	3.75
1.9	1.5	50	5.5	50	2.5	1.75	3.25
2.4	1.5	0	5.5	50	2.25	3.25	3.75
3.3	3.5	0	4	25	1	0.25	4.5
2.5	3.5	0	4	25	0.25	0.75	5
*	28.2	25	16	0	2	1.75	3
*	2	0	7.4	50	0.5	1.75	5.25
2.1	12	50	14.6	25	2.75	2.25	2.5
2.3	14	0	8	25	1.25	0	3.5
3.3	13	25	19	75	0	1.75	3
2.3	16.5	50	15.5	0	0.5	0.25	4.75
1.5	32.4	100	15.3	50	2.25	2.5	3.75
2.1	32.4	25	15.3	0	2	1	4
2.3	4	0	5	0	1.75	1	3.25
*	17.3	0	19	50	1	0	6.25
*	20.4	50	12.9	25	2.75	1.5	3
*	25	25	19.6	50	0.25	1	6.25
*	52.7	75	20.3	75	1.5	1.5	5.5
*	52.7	50	20.3	50	-0.75	-0.25	6.75
*	14.8	0	8.8	0	0.75	0.75	5
*	14.8	0	8.8	25	-1	0	6
*	19.2	50	8	50	2	1	3.75
2.3	15.8	27.0	12.2	32.0	1.2	1.2	4.4
0.6	12.6	27.9	5.3	23.4	1.1	1.0	1.2
14	19	25	19	25	25	25	25

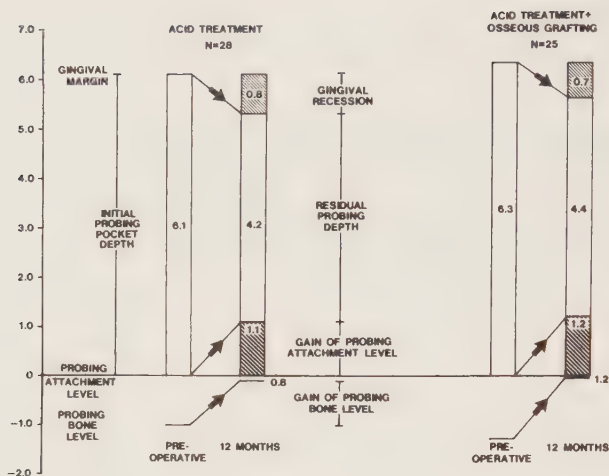


Fig.2. Schematic illustration of the mean effects of acid treatment and acid treatment and osseous grafting. The figure shows what happened to the initial probing pocket depths in terms of the amounts of gingival recession, the amounts of gain of probing attachment level and the residual probing depth in mm. The pre- and post-operative probing bone levels relative to the probing attachment levels are also depicted.

The treatment resulted in a mean gain of probing attachment of 1.1 mm for acid treated and 1.2 mm for acid treated and grafted defects. The probing bone level improved a mean of 0.8 mm for acid treated and 1.2 mm for acid treated and grafted sites. The mean preoperative probing pocket depths of 6.1 mm and 6.3 mm for the two groups were reduced to 4.2 and 4.4 mm respectively. Analyses of variance compensating for existing differences between the two groups with respect to different defect characteristics did not demonstrate any statistically significant differences between the two modalities of therapy for any one of the three parameters of healing.

Table 2 presents the results of treatment by operator. Similar amounts of gain of probing attachment level and gain of probing bone level were found for each of the three operators. For the residual probing depth the analysis of variance demonstrated operator dependency below the 0.05 probability level.

Table 2. Healing results by operator. Means, standard deviations and number of defects.

Operator	Change of probing attachment level (mm)		Change of probing bone level (mm)		Residual probing depth (mm)	
	Acid treated	Acid treated and grafted	Acid treated	Acid treated and grafted	Acid treated	Acid treated and grafted
I	1.2 $\pm$ 0.9 (N=8)	1.5 $\pm$ 1.0 (N=7)	0.7 $\pm$ 0.5 (N=8)	1.3 $\pm$ 1.0 (N=7)	3.9 (N=8)	3.5 (N=7)
II	0.9 $\pm$ 1.1 (N=11)	1.3 $\pm$ 0.9 (N=10)	0.7 $\pm$ 1.2 (N=11)	1.5 $\pm$ 1.0 (N=10)	4.3 (N=11)	4.2 (N=10)
III	1.1 $\pm$ 0.4 (N=9)	0.8 $\pm$ 1.3 (N=8)	1.0 $\pm$ 0.7 (N=9)	0.7 $\pm$ 0.7 (N=8)	4.4 (N=9)	5.3 (N=8)

Table 3. Results of therapy based on recordings of each defect from the aspect (buccal or lingual) with the deepest initial probing pocket depth (see text). Means and standard deviations.

	Preoperative probing pocket depth (mm)	Gain of probing attachment level (mm)	Gain of probing bone level (mm)	Residual probing pocket depth (mm)
Acid treated defects (N=28)	6.5 $\pm$ 0.8	1.1 $\pm$ 1.0	0.8 $\pm$ 0.9	4.3 $\pm$ 0.9
Acid treated and grafted defects (N=25)	6.6 $\pm$ 0.7	1.4 $\pm$ 1.1	1.4 $\pm$ 1.0	4.5 $\pm$ 1.2

The healing results of Tables 1A and 1B were calculated from means of buccal and lingual measurements at each defect site. In sites where the initial probing depth from one of the buccal or lingual aspects are deeper than the other, these means may not describe the changes occurring in the deepest part of the defects. Accordingly, in Table 3 the results of therapy are presented using means of buccal and lingual recordings for the defects with corresponding buccal and lingual initial pocket depth and using single recordings from the deepest probable aspect (buccal or lingual) for the defects with different buccal and lingual initial probing depth. Compared to the results in Tables 1A and 1B and Fig. 2, where the means of buccal and lingual recordings are consistently used, this data demonstrates slightly more gain of probing attachment and probing bone level following the acid treatment and grafting procedure. The difference in gain of probing bone level comparing acid treated and grafted versus acid treated defects proved to be statistically significant at the 0.05 probability level.

DISCUSSION

The present study used two methods to enhance regeneration following surgical treatment of periodontal defects: citric acid conditioning of the root surfaces and grafting of autogenous cancellous bone. Both therapies, e.g. citric acid conditioning alone and acid conditioning combined with osseous grafting resulted in approximately 1 mm gain of probing attachment and probing bone levels. This amount of improvement is less than what has been reported by several authors following treatment of intra-osseous defects (Carraro et al. 1976, Froum et al. 1976, Rosling et al. 1976, Polson & Heijl 1978, Movin & Borring-Møller 1982). Compared to the results of these studies and also compared to the results of one of our previous studies (Renvert & Egelberg 1981) it appears that neither of the methods used accomplished more improvement than what would have been expected following surgical therapy without supplementary regenerative techniques.

The limited gain in probing attachment level obtained in the present study compared to previous studies may partly be explained by the use of a standardized probing force at 0.75 N. A standardized probing force eliminates the possibility of inadvertently introducing a lesser probing

force postoperatively because of concern about penetrating any attachment or adhesion that may have been achieved. The use of a lower probing force postoperatively compared to preoperatively will result in a relative increase in the magnitude of the recorded probing attachment gain (van der Velden 1980, Proye et al. 1982, Chamberlain et al. 1984a).

A probing force of 0.75 N may represent somewhat heavy probing (Hassell et al. 1973, Freed et al. 1983), particularly in combination with a probe tip diameter of 0.50 mm. This probing may cause penetration of the probe tip beyond the apical termination of the junctional epithelium, not only preoperatively but also postoperatively (Listgarten 1980, Magnusson & Listgarten 1980, Caton et al. 1981, Jansen et al. 1981, van der Velden & Jansen 1981, Fowler et al. 1982, van der Velden 1982). This could possibly result in a smaller magnitude of the recorded probing attachment gain compared to a lighter probing force. However, the findings by Chamberlain et al. (1984a) comparing recorded gains of probing attachment at probing forces of 0.25, 0.50 and 0.75 N suggest the opposite situation. The recorded probing attachment gains were actually found to be larger with a probing force of 0.75 N than with a force of 0.25 N.

The discrepancy in amounts of regeneration between some of the previous reports (i.e. Dragoo & Sullivan 1973, Hiatt & Schallhorn 1973, Polson & Heijl 1978) and the present study may possibly be explained by differences in case selection. These previous reports have reported substantially greater amounts of regeneration than did this study. These successful results may have been dependent upon careful case selection. In contrast, case selection for an experimental study of the type employed here is more rigid and is based upon objective criteria followed by randomized distribution of the defects into treatment modality groups. It is conceivable that a greater percentage of defects with a limited potential for regeneration is selected when using such a design.

Variation in postoperative management may account for differences in results (i.e. use of systemic antibiotics, use of repeated intrasulcular curettage). Intensive postoperative plaque control and frequent recall visits have been found to positively affect the amount of regeneration of osseous defects (Rosling et al. 1976, Froum et al. 1982). The magnitudes of the postoperative local site plaque scores and the postoperative local

site bleeding scores of the present study (23-32%) indicate that the patient compliance was not optimal in the subjects under investigation and may explain some of the differences in results between this and other studies.

Another reason for the overall limited effect of the present study may be that the majority of treated defects had a comparatively shallow preoperative depth. In fact, some of the defects may even be somewhat smaller than what their millimeter numbers indicate due to the angulation of the probe during measurements of their depth. Analyses of a multitude of defects from our series of studies demonstrate more gain of probing attachment and probing bone levels in deeper compared to shallower defects (Renvert et al. 1984).

The use of comparatively shallow sites may also explain why osseous grafting failed to be of benefit. Osseous grafts may be of value primarily in deep pockets. This is somewhat supported by the fact that selection of the deepest preoperative pocket depth of each site for treatment evaluation produced a statistically significant difference in favor of osseous grafting for the gain of probing bone levels (Table 3). However, previous studies comparing osseous grafting to non-grafting procedures have obtained varying results regarding the value of osseous grafts (Carraro et al. 1976, Froum et al. 1976, Altieri et al. 1979, Pearson et al. 1981, Movin & Borring-Møller 1982). Therefore, the results of the present study could represent an overall lack of significant effect of osseous grafts.

The limited gain in probing attachment level was combined with a corresponding limited gain in probing bone level. Similarity between magnitudes of gain of probing attachment level and gain of probing bone level following treatment of intraosseous defects has been observed in other studies (Renvert et al. 1981, Renvert & Egelberg 1981, Froum et al. 1982, Chamberlain et al. 1984b, Renvert et al. 1984). A surgical re-entry procedure for the purpose of renewed open bone measurements was not performed in the present study. It is conceivable that such measurements would have demonstrated more bone fill of the defects following osseous grafting than following acid treatment alone. However, this seems less likely in view of our previous finding that evaluation of results following treatment of osseous defects using open bone measurements correlates with

evaluations using both probing attachment and probing bone level measurements (Renvert et al. 1981). On the other hand, the study by Rabalais et al. (1981) on the effect of grafts of nonresorbable ceramic demonstrates that probing attachment level measurements and open measurements do not always correlate.

Citric acid conditioning of the root surfaces was utilized for both grafted and non-grafted defects of the present study. Therefore, this study does not allow a direct evaluation of the value of acid conditioning. However, the overall limited improvement indicates that acid conditioning is of questionable benefit. This underscores the limited advantage to acid conditioning found in our previous human clinical trials (Cole et al. 1981, Renvert & Egelberg 1981) and contrasts somewhat with our findings in human biopsy specimens and in monkeys and dogs where acid conditioning has been found to be a prerequisite to achieve new attachment (Crigger et al. 1978, Cole et al. 1980, Nilvéus & Egelberg 1980, Nilvéus et al. 1980, Klinge et al. 1981). The contrasting results emphasize that extrapolation of results from limited human biopsy material and from experimental animal models to human clinical situation should be made with extreme caution.

The development of postoperative soft tissue interdental craters was observed in all recorded sites. The mean crater depth from measurements at 1, 2 and 3 weeks postoperatively ranged from 0.3 mm to 5.0 mm with group means of 2.3 mm and 2.4 mm. It is possible that the development of soft tissue craters is a common or unavoidable phenomenon following periodontal flap surgery of intraosseous defects. Dragoo & Kaldahl (1983) also found soft tissues craters occurring regularly following various types of regenerative procedures.

A separate analysis of regression was performed to study the relationship between postoperative soft tissue crater depth and healing for those sites where soft tissue crater depths were recorded (N=32). A statistically significant inverse correlation was found between the depth of postoperative soft tissue craters and gain of probing attachment level ($r=-0.40$, $p < 0.05$). Thus, deeper interdental craters were associated with less gain of probing attachment levels. The cause and effect aspect of this relationship seems open to question. Soft tissue craters may

develop immediately postoperatively due to inadequate flap adaptation and may interfere with the subsequent healing process. Alternatively, development of the soft tissue craters may occur as a result of other events that compromise the healing. Factors such as incomplete formation of a blood clot in the defect, nutritional deficiencies of the interdental flap margins combined with the surgical trauma may adversely affect the healing and result in reduced probing attachment gain along with formation of soft tissue craters.

It is conceivable that the high frequency of the soft tissue craters in the present study represents a deleterious effect of the use of citric acid during the surgical procedure. However, this seems unlikely considering the histological findings in dogs by Crigger et al. (1983). This study failed to demonstrate any side effects of citric acid used during interdental flap surgery.

Three different operators were used to treat the defects of the present study with the purpose of finding out if differences in techniques between operators may account for differences in healing results. Although the number of defects treated by the various operators was limited, the results demonstrated no differences in gains of probing attachment and probing bone levels between the three operators. The analyses of variance showed that residual probing depth was the only postoperative parameter with operator dependency. Thus, under the conditions of the present study, variation in techniques during performance of the initial surgical procedures did not significantly influence the therapeutic outcome.

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Paper IV

HEALING AFTER TREATMENT OF PERIODONTAL
INTRAOSSEOUS DEFECTS

IV. Effect of a non-resective versus a
partially resective approach

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Running Head: Healing of intraosseous defects

Key words: Periodontal healing - citric acid -
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ABSTRACT

Two regenerative surgical approaches using citric acid conditioning, were compared to the treatment of deep intraosseous periodontal defects. The first approach was non-resective in that no osseous tissue was removed. The second, a partially resective approach, involved reduction of the osseous defect depth by removal of some supporting bone. 16 patients and a total of 26 defects, with probing pocket depth ≥ 7 mm, were included in the study. The depths of the corresponding osseous defect, as revealed during surgery were ≥ 5 mm.

The results demonstrated mean gains in probing attachment level of 0.7 mm for the partially resected group and 1.1 mm for the non-resected group. Corresponding gains in probing bone levels were recorded in the defect sites for each group. Probing pocket depth was reduced from 7.5 mm to 4.0 mm in the partially resected group and from 7.9 mm to 5.3 mm in the non-resected group. Both procedures caused loss of attachment and bony support from adjacent tooth surfaces involved by the surgical procedure. Slightly more loss of attachment and bone was experienced by the partially resected group (range 1.2 - 1.5 mm) than the non-resective group (range 0.1 - 0.9 mm).

INTRODUCTION

It has been an assumption in periodontal therapy that the increased pocket depth associated with periodontitis should be reduced to prevent further progression of attachment loss. For the treatment of deep periodontal pockets associated with intraosseous defects contrasting surgical approaches have been advocated. One is regenerative surgery with a goal of gaining new connective tissue attachment and bony fill to close the apical part of the periodontal defect. A potential drawback with this approach is that significant residual probing depth may remain as an unresolved concern.

A second surgical possibility is a resective approach. This involves a reduction of the gingival tissues from a coronal direction and often necessitates osseous resection to eliminate the intraosseous defect. This resection frequently requires removal of bone from tooth surfaces not directly involved by the defect and usually results in attachment loss on

adjacent tooth surfaces. This concern often leads to a compromise approach with only partial resection of the walls of the osseous defects.

In the present study two forms of regenerative surgery were compared: 1) a regenerative procedure with no manipulation of the osseous tissue (referred to as the non-resective approach) and 2) a regenerative procedure where some osseous resection was performed (referred to as the partially resective approach). Both therapies were supplemented with citric acid conditioning of the root surfaces for the purpose of augmenting the regenerative potential during healing (Cole et al. 1980, Cole et al. 1981, Renvert & Egelberg 1981). The results of the two treatment modalities were compared with respect to changes in probing bone levels, probing attachment levels, probing pocket depth and gingival recession.

MATERIALS AND METHODS

Subjects

16 patients, ages 19 to 74 (mean 44 years), with deep intraosseous periodontal defects, participated in the study. A total of 26 defects were treated (14 non-resective and 12 partially resective). All patients received initial therapy consisting of oral hygiene instruction and root planing. This initial phase of treatment extended from 7 to 38 weeks (mean 18 weeks) prior to the designated surgical therapy. Patient selection was based on the following criteria at reevaluation: 1) presence of at least one proximal area with a residual probing pocket depth ≥ 7 mm; 2) an associated intraosseous defect which was proven to be ≥ 5 mm deep as measured during surgery; 3) no history of previous periodontal surgery in the area. Defects adjacent to teeth with root furrows or furcation apertures were not included in the study.

Parameters

Records of parameters were made according to the schedule shown in Table 1.

Six aspects of each tooth were recorded: mesio-buccal, mid-buccal, disto-buccal, mesio-lingual, mid-lingual and disto-lingual. Probing measurements were taken from the defect tooth as well as from the proximal, buccal and lingual surfaces of the tooth adjacent to the defect. All measurements throughout the study were made by one and the same examiner.

Table 1. Parameters and schedule of recordings.

Parameter	Time point of recording			
	Pre-operatively	During surgery	6-week postop intervals	6-months postop
Plaque scores	X		X	X
Bleeding on probing	X			X
Probing pocket depth	X			X
Probing attachment level	X			X
Probing bone level	X			X
Gingival recession				X
Number of tooth surfaces involved		X		
Osseous defect circumference		X		
Number of osseous walls of defect		X		
Depth of 3+2+1-, 3+2- and 3-wall components of defect		X		
Immediate postoperative probing depth		X		

Plaque scores: Plaque was disclosed by swabbing the teeth with an erythrosine dye (Trace[®], Lorvic Corporation, St. Louis, MO, U.S.A.). Areas adjacent to the gingival margin which exhibited a deep stain which could easily be removed with the side of the probe were scored as having plaque. Plaque scores were expressed as the percentage of total surfaces under evaluation which revealed the presence of plaque. Two types of plaque scores were calculated: 1) full mouth plaque scores based upon the

six aspects of all teeth in the mouth; 2) local site plaque scores, based upon the buccal and lingual aspects of the proximal surface involved by the defect. Mean postoperative full mouth plaque and mean postoperative local site plaque scores were averages calculated from the recordings from all four of the 6-week postoperative intervals throughout the study.

Bleeding on probing: Presurgical evaluation of bleeding on probing was determined immediately prior to the probing pocket depth measurements. Measurements were made using an electronic pressure sensitive probe (Electronic Periodontal Probe, Model 200, Vine Valley Research, Middlesex, N.Y., U.S.A.) with a 0.5 mm diameter probe tip machined in 1 mm increments and a standardized probing force of 0.50 N. Postoperative bleeding scores were obtained at the 6 months evaluation.

Probing pocket depth and probing attachment level: Measurements of probing pocket depth and probing attachment level were made using the same pressure sensitive probe. Each site was probed under local anesthesia three consecutive times using three increasing probing forces of 0.25, 0.50 and 0.75 N. The probe was moved apically twice at each probing force to assure maximum penetration of the probe. Recordings were made to the nearest 0.5 mm. A vacuum-adapted soft acrylic onlay (Scheu-Dental, Iserlohn, West Germany) was used to provide reference points for the probing attachment level measurements. The probe was placed at the anatomic mid-buccal and mid-lingual aspects of the tooth and directed longitudinally for the mid-buccal and mid-lingual measurements. For the proximal measurements the probe placement was guided by the interdental indentations of the onlay and the probe was directed apically toward the anatomic mid-proximal aspect of the root surface. Probing pocket depth was measured from the gingival margin to the tip of the probe. Probing attachment level was measured from the onlay margin to the tip of the probe. Means of the recordings from the buccal and lingual aspects were calculated for the proximal defect sites and for the proximal surfaces of the adjacent teeth. Also, means of mid-buccal and mid-lingual measurements were calculated for the defect teeth and for the adjacent teeth. For the purpose of this study the recordings at 0.75 N were used.

Probing bone level: Immediately after probing pocket depth and attachment level measurements were completed, probing bone level measurements were

taken using a similar probe tip. The probe was forced through the soft tissue toward the bone until definite resistance was met. The probing bone level was recorded as the distance from the onlay margin to the probe tip. Means were calculated as for probing pocket and probing attachment level measurements.

Gingival recession: Gingival recession was calculated by change in the distance from the onlay margin to the gingival margin.

Number of tooth surfaces involved: The number of tooth surfaces involved at the apical portion of the defect was recorded as 1 if the defect was localized to the proximal tooth surface only, as 2 when the defect also encompassed the buccal or lingual surface, and as 3 when proximal, buccal and lingual surfaces were involved.

Osseous defect circumference: The circumference of the osseous defect at the coronal portion of the defect in relation to the root circumference was evaluated after debridement of the surgical site and estimated to the nearest 30°.

Number of osseous walls: The defect was characterized by overall visual observation according to dominant form as to 1-wall, 2-wall or 3-wall defect.

Depth of 3+2+1-, 3+2- and 3-wall components of the osseous defect: The osseous defect depth was recorded after debridement of the surgical site and, for the partially resective sites, again immediately following osteoectomy and osteoplasty. Measurements were taken using the same calibrated probe tip and onlays as for preoperative probing bone level measurements.

The distance to the fundus of the proximal defect (F) was measured from both buccal (SB) and lingual (SL) onlay margins (Fig.1). The crest of the buccal wall of the defect (B) was measured from the buccal onlay margin. The crest of the lingual wall of the defect (L) was measured from the lingual onlay margin. The crest of the proximal wall (P) of the defect was measured from both buccal and lingual onlay margins. The height of the buccal wall was calculated by subtracting its crest level measurement from the buccal measurement of the fundus of the osseous defect.

Similarly, the lingual wall height was calculated from the corresponding lingual measurements. To calculate the height of the proximal wall, the average of the buccal and lingual measurements of its crest was subtracted from the average of the buccal and lingual measurements of the apical extent of the defect.

In this way the depths of the defect could be expressed relative to the number of walls of the defect. Consequently the depth of the defect was given for the 3-wall, 3+2-wall and 3+2+1-wall components of the defects (Fig.1). The figures give only approximate representation of the defect components due to the fact that angulation of the probe had to be varied to obtain the different measurements.

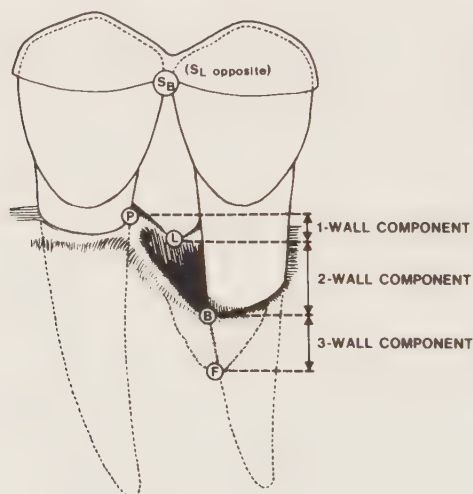


Fig.1. Drawing illustrating the 1-, 2- and 3-wall components of an osseous defect and the points of measurements during surgery.

SB = Buccal margin of stent

SL = Lingual margin of stent

P = Crest of the proximal wall of the osseous defect

B = Crest of the buccal wall of the osseous defect

L = Crest of the lingual wall of the osseous defect

F = Fundus of the osseous defect

Immediate postoperative probing depth: After suturing of the tissue flaps the probing depths were measured from the buccal and lingual aspects of the proximal defect sites by recording the distance from the gingival flap margin to the most apical extent of the defect. Means of the two recordings were calculated for each defect site.

Treatment procedures

Two types of regenerative surgical procedures were performed and are referred to as the partially resective approach and the non-resective approach. In either case an inverse bevel incision with appropriate scalloping was made followed by the reflection of a full thickness flap. Granulomatous tissue was removed exposing the osseous walls. The roots were carefully planed. Defects assigned the partially resective approach were treated by osseous reduction to facilitate apical positioning of the flaps. The amount of osseous reduction that was performed varied, due to concern about sacrificing supporting bone, yet the reduction was enough to assure an immediate postoperative probing depth of < 6 mm. The root surfaces exposed by the osseous defects were treated by a 3-minute topical application of saturated citric acid using cotton pledgets. Pledgets which darkened during the application period due to incomplete hemostasis were replaced. The area was profusely irrigated with water following the acid conditioning procedure. The flaps in both groups were thinned and apically positioned. Thus, some apical positioning also occurred in the non-resected group due to removal of tissue with the initial incision and during the subsequent debridement and flap management. Complete interdental wound closure was achieved in both groups. After interrupted suture placement, pads of Telfa[®] (Colgate-Palmolive Co., New York, N.Y., U.S.A.) coated on the tissue side with tetracycline ointment (Aureomycin, 3 %, Lederle, Pearl River, N.Y., U.S.A.) were positioned interdentally to cover the sutured papillas. Coe-pack[™] (Coe Laboratories Inc., Chicago, IL, U.S.A.) dressing was then placed over the surgical area.

One week after surgery, sutures were removed and new Telfa[®] pads and dressing were placed. After one more week the second dressing was removed and the patient was placed on twice daily rinses of 0.2 % chlorhexidine (Hibitane[®], Imperial Chemical Industries Ltd., Macclesfield, Great Britain) for three weeks (until five weeks postoperatively). Six weeks postoperatively and at each subsequent 6-week interval, the patients were

recalled for plaque scores, reinstruction in oral hygiene as needed, and rubber cup prophylaxis. This was continued until six months after surgery when final measurements were taken.

Statistical analyses

Analyses of variance were utilized to evaluate the effect of treatment as observed by probing attachment and probing bone level changes and by the residual probing depth at 6 months. Various combinations of defect characteristics were used as covariates.

RESULTS

Plaque and bleeding scores

Preoperative mean full mouth bleeding scores of the non-resected group and of the partially resected group were 12.3 % and 15.3 % respectively (Tables 2 and 3). At 6 months the corresponding scores were 13.6 % and 19.3 % respectively (Tables 4 and 5). The mean full mouth plaque score throughout the postoperative period was 10.2 % and 15.4 % for the non-resected and partially resected groups respectively (Tables 4 and 5).

Defect sites

Both the non-resected and the partially resected groups were comprised of deep periodontal lesions as observed from the preoperative probing pocket depths (means of 7.9 mm and 7.5 mm respectively) and the osseous defect depths (means of 6.9 mm and 5.9 mm respectively)(Tables 2 and 3). The immediate pocket reduction objective in the partially resected group was accomplished as evidenced by a 3.4 mm difference in the mean immediate postoperative probing depth between the two groups (means of 8.2 mm and 4.8 mm respectively). The immediate postoperative probing depth was < 6 mm for all partially resected sites as contrasted to $\geq$ 7 mm for all non-resected sites.

The initial mean probing pocket depth of 7.9 mm for the non-resected sites was reduced to a mean residual probing depth of 5.3 mm (Table 4). This 2.6 mm reduction was accomplished by a mean gain of probing attachment level of 1.1 mm and 1.5 mm of mean gingival recession (Fig.2).

For the partially resected sites, the mean preoperative probing pocket depth of 7.5 mm was reduced to a mean residual probing depth of 4.0 mm (Table 5). This 3.5 mm reduction was accomplished by a mean gain of probing attachment level of 0.7 mm and 2.8 mm of mean gingival recession (Fig.2). The results for probing bone level showed a mean gain of 1.2 mm in the non-resected group and 0.7 mm in the partially resected group (Tables 4 and 5; Fig.2).

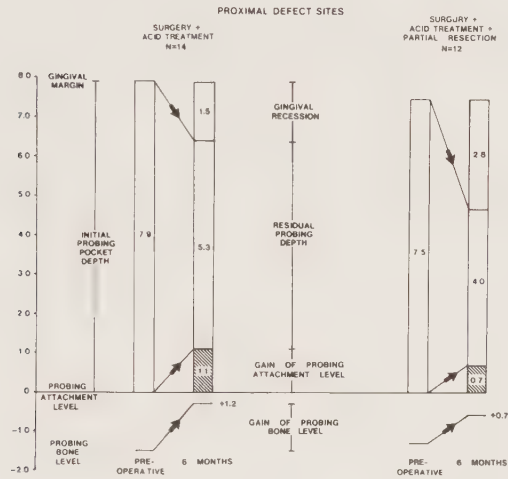


Fig.2. Schematic illustration of the mean effects of non-resective and partially resective surgery for the proximal defect sites. The figure shows what happened to the initial probing pocket depth in terms of the amounts of gingival recession, the amounts of gain of probing attachment level, gain of probing bone level, and the residual probing depth in mm. The pre- and postoperative probing bone levels relative to the attachment levels are also depicted.

Table 2. Baseline characterization of the non-resected defect sites.

Subject	Site	Osseous Defect Characteristics			
		Initial full mouth bleeding score %	Probing pocket depth (mm)	Number of tooth surfaces involved	Defect circum- ference (degrees)
1	21 M	8	7.5	2	120
2	11 M	*	9.25	3	270
3	24 D	16	7	1	60
	26 D	16	5.5	2	90
4	36 D	13	8	2	120
6	15 M	11	5.75	3	270
8	36 M	17	6	1	60
	37 M	17	8	1	90
10	37 M	8	8.25	2	120
	35 D	8	11.25	4	360
11	36 M	15	9.25	1	90
12	46 D	12	9.75	2	90
14	47 M	8	8	*	*
10	36 D	15	7.5	1	90
Mean		12.3	7.9	1.9	141
S.D.		3.5	1.6	1.0	95
N		10	14	13	13

* Data not available

Number of osseous walls	Depth of 3+2+1-wall component (mm)	Depth of 3+2-wall component (mm)	Depth of 3-wall component (mm)	Immediate postoperative probing depth (mm)
3	5	1.5	0.5	*
2	5.5	5	0	9.75
3	9	9	7	10.5
2	6	5.5	3.5	8
2	8	6.75	2.5	8.5
3	6.75	4.5	2.5	7
3	6.5	5.25	4.5	7
2	8	5	4.5	7
3	7.5	6.5	3.5	9.5
1	7	7	5.5	7.5
2	6.25	5.5	4	7
3	8	5.75	4.5	9.25
*	6.5	5	4	7.5
3	6	5	4.75	8
2.5	6.9	5.5	3.7	8.2
0.7	1.1	1.6	1.8	1.2
13	14	14	14	13

Table 3. Baseline characterization of the partially resected defect sites.

Sub- ject	Site	Osseous Defect Characteristics						
		Initial full mouth bleeding score %	Probing pocket depth (mm)	Number of tooth surfaces involved	Defect circum- ference (degrees)	Number of osseous walls	Pre-resection Depth	
							Depth of 3+2+1-wall component (mm)	Depth of 3+2-wall component (mm)
1	43 M	8	8.5	2	120	3	5	4.5
3	35 D	16	7	2	60	3	4.5	4
	36 D	16	7.75	1	60	2	5	4
5	36 D	19	5.5	2	120	2	8	5.75
7	21 D	21	8.5	2	120	2	6.5	6
9	25 M	4	7.5	2	120	2	6	5.25
	35 M	4	6	2	150	2	5	4.5
11	46 M	15	8.5	1	90	2	6	5.25
13	13 M	19	7.5	3	180	2	6.75	6.5
15	36 D	21	7.75	2	120	2	7.5	5.5
	34 M	21	7	1	90	3	4.5	4
16	46 M	15	8	1	90	3	5.75	5
Mean		15.3	7.5	1.8	110	2.3	5.9	5.0
S.D.		5.9	1.0	0.6	35	0.5	1.1	0.8
N		9	12	12	12	12	12	12

* Data not available

Depth of 3-wall component (mm)	Post-resection Depth			Immediate postoperative probing depth (mm)
	Depth of 3+2+1-wall component (mm)	Depth of 3+2-wall component (mm)	Depth of 3-wall component (mm)	
2	3	3	2	*
3	2.75	2.5	2	4.25
0	2.5	2	0	4.75
0	4	3.75	0	4
5	5	4.5	3.5	5.75
5	4.5	3	2.5	5.75
3.5	2.5	2.25	1.5	3.5
2	3	2.5	1	4
5	5.5	4.5	3	5.5
0	4.25	4	0	5.75
2.5	2.5	2.25	1	3.5
4	3.25	3	3	5.5
2.7	3.6	3.1	1.6	4.8
1.9	1.1	0.9	1.2	0.9
12	12	12	12	11

Table 4. Postoperative recordings of the non-resected defect sites.

Sub- ject	Site	Mean post- operative full mouth plaque score %	Mean post- operative local site plaque score %	Final full mouth bleeding score %	Change of probing attachment level (mm)	Change of probing bone level (mm)	Residual probing depth (mm)	Gingival reces- sion (mm)
1	21 M	14.3	25	7	0.75	1	4.75	2
2	11 M	17.3	50	11	2.25	1	6.25	1
3	24 D	15.3	25	15	2.75	2.5	3.5	0.75
	26 D	15.3	37.5	15	1.25	2.25	3	1.25
4	36 D	9	0	9	2	3	4.25	1.75
6	15 M	7	37.5	14	0	-1.25	4.5	1.25
8	36 M	4.3	25	10	0.5	0	5.25	0.25
	37 M	4.3	0	10	1.25	1.25	5	1.75
10	37 M	5.8	25	18	0	1.25	6.25	2
	35 D	5.8	0	18	-0.5	-0.5	9.75	2
11	36 M	10.5	12.5	22	1	1	5.75	2.5
12	46 D	10.5	12.5	21	1.5	2.25	6	2.25
14	47 M	5.2	12.5	8	1	0.25	5.5	1.5
16	36 D	13.3	0	15	2	2.25	5	0.5
Mean		10.2	18.8	13.6	1.1	1.2	5.3	1.5
S.D.		4.4	16.1	5.1	0.9	1.2	1.6	0.7
N		11	14	11	14	14	14	14

Analyses of variance, accounting for the slight differences of preoperative probing pocket depth and defect circumference between the two groups, showed statistically significant differences between the two groups for residual probing depth ($p < 0.01$ and $p < 0.05$ respectively) but no significant differences for gain of probing attachment or gain of probing bone level.

Table 5. Postoperative recordings of the partially resected defect sites.

Sub- ject	Site	Mean post- operative full mouth plaque score %	Mean post- operative local site plaque score %	Final full mouth bleeding score %	Change of probing attachment level (mm)	Change of probing bone level (mm)	Residual probing depth (mm)	Gingival reces- sion (mm)
1	43 M	14.3	75	7	1.5	1.5	5	2
3	35 D	15.3	12.5	15	2.25	2.5	3	1.75
	36 D	15.3	12.5	15	1.5	2	3.25	3
5	36 D	12.6	5.0	18	0	0	2.75	2.75
7	21 D	36.5	87.5	17	1.5	1	3.75	3.25
9	25 M	4	0	24	0.5	-0.25	4.5	2.5
	35 M	4	25	24	0	-0.25	4	2
11	46 M	10.5	25	22	0.5	0.25	4.75	3.25
13	13 M	11	62.5	30	-1.5	-1.5	4	5
15	36 D	20.7	37.5	26	1.25	2.5	4.25	2.25
	34 M	20.7	25	26	0.25	-0.25	4	2.75
16	46 M	13.3	37.5	15	0.5	0.5	4.25	3.5
Mean		15.4	37.5	19.3	0.7	0.7	4.0	2.8
S.D.		9.1	26.7	6.9	1	1.3	0.7	0.9
N		9	12	9	12	12	12	12

Adjacent tooth surfaces

The adjacent tooth surfaces (buccal/lingual of defect tooth, proximal of adjacent tooth, buccal/lingual of adjacent tooth) demonstrated some loss of probing attachment level and probing bone level for both non-resected and partially resected groups. The mean loss of probing attachment level ranged from 0.1 to 0.9 mm for the non-resected group and from 1.2 to 1.5 mm for the partially resected group. The mean loss of probing bone level for various surfaces approximated the mean loss of probing attachment level (Figs. 3, 4 and 5).

Analyses of variance demonstrated that the proximal surface of the adjacent teeth had significantly more loss of probing attachment level in the partially resected group than the non-resected group ($p < 0.05$) and correspondingly greater gingival recession ($p < 0.01$). The buccal and lingual surfaces of the adjacent teeth also demonstrated significantly more loss of probing attachment and loss of probing bone level in the partially resected than in the non-resected group ($p < 0.05$). The defect teeth had significantly more loss of bone on the buccal and lingual surfaces in the partially resected group than in the non-resected group ($p < 0.05$).

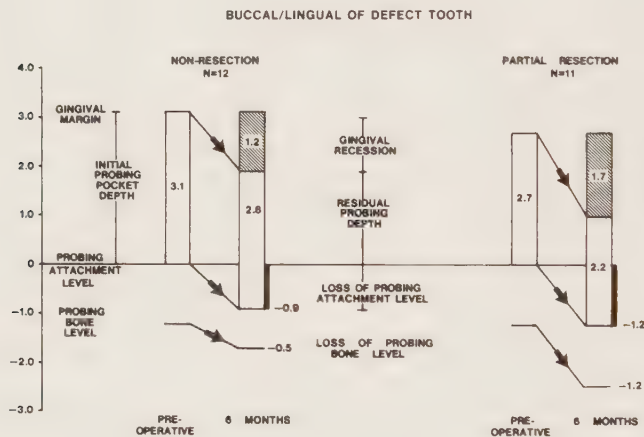


Fig.3. Schematic illustration of the mean effects of non-resective and partially resective surgery for the combined buccal and lingual surfaces of the tooth directly involved by the proximal defects.

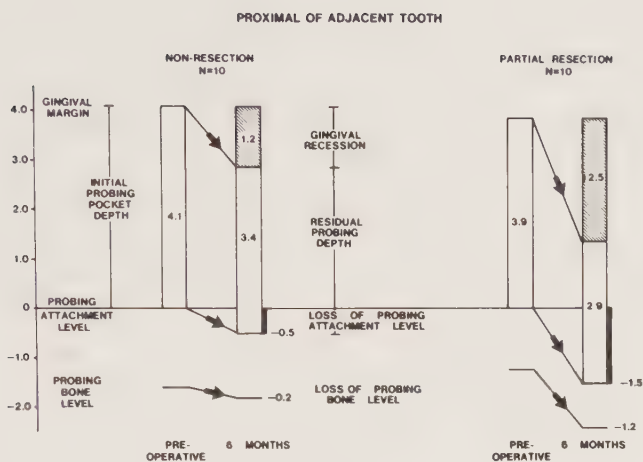


Fig.4. Schematic illustrations of the mean effects of non-resective and partially resective surgery for the proximal surfaces of the adjacent tooth.

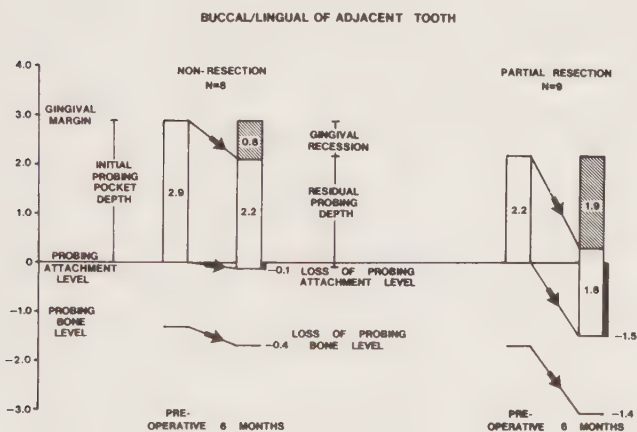


Fig.5. Schematic illustration of the mean effects of non-resective and partially resective surgery for the combined buccal and lingual surfaces of the adjacent tooth.

DISCUSSION

The objective of this study was to determine if a partially resective surgical approach to the treatment of intraosseous periodontal defects would result in less residual probing depth as compared to a non-resective approach while not compromising the potentials for gain in probing attachment level and probing bone level. The selection of sites was limited to defects associated with deep periodontal pockets since surfaces with deep pockets, initially, generally demonstrate the deepest residual probing depths (Knowles et al. 1979). Few patients were found with pairs of "mirror image" sites for contralateral comparison of the two techniques within the same individual. Generally, only one site was available in a given patient. The results of the present study, therefore, have to be interpreted with these limitations in mind.

The methods used to evaluate the effect of therapy were selected to give as much validity and reliability as possible in a clinical study of this nature. Accordingly, fixed reference points of an acrylic stent were used in conjunction with standardized probes and probing force for the probing measurements. The results of previous studies indicate that probing bone level measurements reliably record the actual bone level changes following therapy (Greenberg et al. 1976, Renvert et al. 1981). However, changes in probing attachment level measurements do not necessarily reflect histological changes in connective tissue attachment levels (Listgarten 1980, Magnusson & Listgarten 1980, Fowler et al. 1982). Both treatment modalities resulted in a mean gain for both probing attachment level and probing bone level of approximately 1 mm. This limited gain is in contrast to the greater amount of gain following treatment of intraosseous defects previously reported by some authors (Carraro et al. 1976, Rosling et al. 1976, Polson & Heijl 1978, Movin & Borring-Møller 1982, Renvert & Egelberg 1981). Limited gain, comparable to the results of the present study, has been observed by others (Froum et al. 1976, Altieri et al. 1979, Isidor 1981, Pearson et al. 1981, Rabalais et al. 1981, Froum et al. 1982, Renvert et al. 1984). The discrepancies in results comparing the various studies may relate to differences in patient and site selection and mode of therapy, including varying amounts of pre- and post-operative therapy. Also, the methods of measurements vary between the studies. The use of standardized probing in future studies of this nature

may help to clarify the discrepancies. In fact, recent studies have highlighted the variation in probing results which were obtained following use of different probing forces (van der Velden & Jansen 1980, Proye et al. 1982, Chamberlain et al. 1984).

Citric acid conditioning of the instrumented root surfaces was included in the therapy for both the non- and partial resection groups. The acid conditioning was included because previous animal and human studies have demonstrated that with this procedure, new connective tissue attachment can be accomplished, in contrast to a long junctional epithelium (Crigger et al. 1978, Cole et al. 1980, Nilvéus & Egelberg 1980, Nilvéus et al. 1980, Bogle et al. 1981, Klinge et al. 1981, Steiner et al. 1981, Polson & Proye 1982, Proye & Polson 1982, Bogle et al. 1983). In a previous study on treatment of intraosseous defects in humans, acid conditioning resulted in somewhat more gain of probing attachment levels than non-acid treated controls (Renvert & Egelberg 1981). The overall limited gain of probing attachment level in the present study, however, suggests that the acid conditioning had limited effect. A similar limited gain of probing attachment following use of citric acid was observed in another recent study on treatment of intraosseous defects (Renvert et al. 1984). Thus, a pattern of findings seems to emerge from the studies on citric acid conditioning in our laboratory. Acid conditioning has consistently proved to be a prerequisite to obtain new attachment in our animal models. However, the beneficial effects as reflected by change in probing attachment levels in humans seem to be limited with techniques presently available.

In this study the mean residual probing depth six months postoperatively was 4.0 mm for the partially resected group as compared to 5.3 for the non-resected group. This difference was a logical outcome because of the specific therapeutic attempt that was made to reduce the height of the gingival flap margin immediately postoperatively in the partial resection group.

The results of the present study, for tooth surfaces adjacent to the defect sites, show a general loss of probing attachment and probing bone levels for both treatment groups with the greatest loss occurring in the partially resected group. These losses of tooth support are similar to what has been previously reported by others (Pennel et al. 1967, Donnenfeldt et al. 1970, Wilderman et al. 1970, Smith et al. 1980, Moghaddas &

Stahl 1980). The greater loss in the partially resected group can be related to the osteoplasty and osteoectomy performed in this group.

In conclusion, the results after six months comparing a non-resective and a partially resective approach to the treatment of deep intraosseous defects demonstrated limited differences between the two procedures. The amount of regeneration which can be achieved seems to be modest following both procedures. Therefore, the selection of a procedure for an individual site ought to be based upon the ramifications of greater sacrifice of attachment on adjacent tooth surfaces in the partially resective approach in contrast to the possible disadvantage of relatively deeper residual probing depth in a non-resective approach. Indeed, in terms of actual periodontal support a question must be raised in terms of the overall regenerative value of either surgical procedure.

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Paper V

HEALING AFTER TREATMENT OF PERIODONTAL
INTRAOSSEOUS DEFECTS

V. Effect of root planing versus flap surgery

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Running Head: Healing of intraosseous defects

Key words: Periodontal healing - citric acid -
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ABSTRACT

The present study compared surgical therapy to root planing alone in the treatment of periodontal intraosseous defects. 25 defects in 14 patients were subjected to root planing only and another 25 defects in the same patients were surgically exposed and citric acid treated. The healing response was evaluated six months after treatment. The mean gain of probing attachment level was 0.8 mm in the root planed defects as compared to 1.3 mm for the surgically exposed and acid treated defects. The probing bone level improved an average of 0.2 mm for the root planed areas as compared to 0.6 mm for the acid treated defects. The mean preoperative probing pocket depth of 6.7 mm and 6.8 mm for the two groups were reduced to 5.2 mm and 4.1 mm respectively. The differences in these parameters were statistically significant between the two groups. However, both groups demonstrated limited regeneration.

INTRODUCTION

Different surgical techniques have been used in attempts to obtain regeneration of periodontal intraosseous defects. Improved clinical attachment levels and bone apposition have been reported by several authors following procedures with or without the use of graft materials placed in the defects (Schallhorn & Hiatt 1972, Carraro et al. 1976, Froum et al. 1976, Rosling et al. 1976, Polson & Heijl 1978, Movin & Borring-Møller 1982).

Citric acid conditioning of the root surfaces has been introduced to enhance the regeneration after periodontal surgery. Findings by Cole et al. (1981) and Renvert & Egelberg (1981) suggest some but limited improvement following acid conditioning as compared to non-acid treated controls. Renvert et al. (1984) combined acid conditioning with osseous grafting of intraosseous defects and compared this to acid conditioning alone. Limited regeneration was observed following both treatment modalities. Similar limited regeneration of osseous defects has been observed in other studies comparing various surgical therapies (Altieri et al. 1979, Pearson et al. 1981, Rabalais et al. 1981, Froum et al. 1982, Chamberlain et al. 1984a).

Non-surgical periodontal therapy of advanced periodontal lesions also results in gain of clinical probing attachment levels (Hill et al. 1981, Pihlstrom et al. 1981, Lindhe et al. 1982a,b, Badersten et al. 1984a,b). A recent six months follow-up of intraosseous defects comparing root planing alone and two surgical treatment modalities failed to demonstrate significant differences in gain of probing attachment levels between non-surgical and surgical approaches (Isidor 1981).

Thus, recent studies on treatment of intraosseous periodontal defects seem to indicate that variations of surgical and regenerative techniques may not significantly affect the therapeutic outcome. In addition, one study suggests that root planing alone may produce similar improvement. The present study was designed to further investigate this problem by comparing a surgical approach using acid conditioning to root planing alone in the treatment of intraosseous periodontal lesions.

MATERIAL AND METHODS

Subjects

14 periodontally involved patients, 32 to 67 years of age, volunteered for the study. Initial therapy consisting of oral hygiene instruction and root planing was performed a minimum of six months prior to final patient and site selection. To be included, patients had to demonstrate a full mouth plaque score less than 15% (see Plaque scores below) and at least two separate proximal sites with radiographic intraosseous lesions and probing pocket depths $\geq$ 6 mm. Defects adjacent to teeth with root furrows, root concavities or furcation apertures were not included in the study. A total of 50 defects were treated (25 root planed and 25 surgically exposed and acid treated).

Clinical parameters

The following parameters were recorded:

- 1) plaque scores
- 2) bleeding upon probing
- 3) probing pocket depth
- 4) probing attachment level

- 5) probing bone level
- 6) osseous defect circumference
- 7) number of tooth surfaces involved
- 8) number of osseous walls of the defects
- 9) depth of 3+2+1-, 3+2- and 3-wall components of the osseous defects
- 10) immediate postoperative probing depth
- 11) immediate postoperative probing attachment change
- 12) postoperative soft tissue crater depth

Probing pocket depths, probing attachment levels, and probing bone levels were determined immediately preoperatively as well as at the final examination 6 months postoperatively. Records of the various osseous defect characteristics were obtained during the surgical procedure. Interdental soft tissue crater depths were measured at 1, 2 and 3 weeks postoperatively. Postoperative plaque scores were recorded at 6, 12, 18 and 24 weeks and postoperatively bleeding upon probing at 12, 18 and 24 weeks. All measurements were made by the same examiner.

Plaque scores: Six aspects of each tooth were examined: mesio-buccal, mid-buccal, disto-buccal, mesio-lingual, mid-lingual and disto-lingual. Plaque was disclosed with an erythrosine dye (Diaplac[®], Astra, Sweden). Areas adjacent to the gingival margin which exhibited a deep stain that could easily be removed with the side of a probe were scored as having plaque. Plaque scores were expressed as the percentage of total surfaces under evaluation which revealed the presence of plaque. Two types of plaque scores were calculated: 1) full mouth plaque scores, based upon the six aspects of all teeth in the mouth, 2) local site plaque scores, based upon the buccal and lingual aspects of the proximal surface involved by the defect. Mean postoperative full mouth and mean postoperative local site plaque scores were averages based upon calculations from the recordings at 6, 12, 18 and 24 weeks postoperatively.

Bleeding upon probing: Bleeding upon probing for the defect sites was recorded following the pocket probing at 0.50 N (see below). Probing for full mouth bleeding scores was also performed using 0.50 N. Mean postoperative full mouth and local site bleeding scores were calculated from the recordings at 12, 18 and 24 weeks postoperatively.

Probing pocket depth and probing attachment level: Measurements of probing pocket depth and probing attachment level were made using an electronic pressure sensitive probe (Electronic Periodontal Probe, Model 200, Vine Valley Research, Middlesex, N.Y., U.S.A.). A specially machined probe tip having 1 mm increments and 0.5 mm diameter was used. Each site was probed three consecutive times using three different increasing probing forces at 0.25 N, 0.50 N and 0.75 N. Recordings to the nearest 0.5 mm were made from the buccal and lingual aspects of the proximal defect sites. A vacuum-adapted soft acrylic onlay was used to provide reference points for the probing measurements (Froum et al. 1975, Badersten et al. 1984c). The placement of the probe was guided by the interdental indentations of the onlay and the probe was directed apically toward the deepest point of the mid-proximal aspect of the root surface. Probing pocket depth was measured from the gingival margin to the tip of the probe. Probing attachment level was recorded from the onlay margin to the tip of the probe. Means of the buccal and lingual recordings for each proximal defect were used to evaluate the effect of treatment. For the purpose of this report the records taken at 0.75 N were used.

Probing bone level: Immediately after probing pocket depth and probing attachment level measurements were completed, probing bone level measurements were taken under local anesthesia using the same probe tip. During probing, the probe was directed apically toward the mid-proximal aspect of the root surface and forced through the soft tissue toward the bone until definite resistance was met. The probing bone level was recorded as the distance from the onlay margin to the probe tip. Means of buccal and lingual recordings were calculated.

Osseous defect circumference, number of tooth surfaces involved and number of osseous walls of the defects: These characteristics were recorded from the surgically treated defects only and after surgical debridement of the sites. The circumference of the osseous defect in relation to the root circumference was estimated to the nearest 30° at the coronal portion of the defect. The number of tooth surfaces involved at the apical portion of the defect was recorded as 1 if the defect was localized to the proximal surface only, as 2 when the defect also encompassed the buccal or lingual surface and as 3 when proximal, buccal and lingual surfaces were involved. The number of osseous walls of the

defects was recorded as 1 when only a proximal wall was present, as 2 if the proximal defect had a buccal or lingual wall and as 3 when both buccal and lingual walls were present.

Depth of 3+2+1-, 3+2- and 3-wall components of the osseous defects: The osseous defect depth was recorded using the onlay margin as reference point for a series of measurements. The distance to the most apical extent of the proximal defect was measured from both buccal and lingual onlay margins. The crest of the buccal wall of the defect was measured from the buccal onlay margin. The crest of the lingual wall of the defect was measured from the lingual onlay margin. The crest of the proximal wall of the defect was measured from both buccal and lingual onlay margins.

The height of the buccal wall was calculated by subtracting its crest level measurement from the buccal measurement of the apical extent of the osseous defect. Similarly, the lingual wall height was calculated from the corresponding lingual measurements. To calculate the height of the proximal wall, the average of the buccal and lingual measurements of its crest was subtracted from the average of the buccal and lingual measurements of the apical extent of the defect. In this way, the depths of the defects could be expressed relative to the number of walls of the defect. Consequently, the depths were calculated for the 3-wall, 3+2-wall and 3+2+1-wall components of the defects. The figures give only approximate representation of the defect components due to the fact that angulation of the probe had to be varied to obtain the different measurements.

Immediate postoperative probing depth: Following suturing the distance from the gingival margin to the fundus of the bony defect was measured. Means of buccal and lingual recordings were calculated.

Immediate postoperative probing attachment change: Immediately postoperatively the distance from the stent margin to the fundus of the bony defect was measured. This distance was subtracted from the preoperative attachment level measurement to determine the immediate postoperative probing attachment change. Means of buccal and lingual recordings were calculated.

Postoperative soft tissue crater depth: The depths of interdental soft tissue craters were measured from the buccal aspect. The distance from the onlay margin to the most apical point of the crater was first measured. Then, the distance from the onlay margin to the most coronal extent of the buccal crater wall was recorded. The crater depth was calculated by subtracting the buccal wall measurement from the apical point measurement. A mean of the 1-, 2- and 3-week recordings was calculated. Again, the computed depths are approximate crater depths due to the difference in probe angulation for the two readings. The measurements were taken using a minimum of force to avoid compression of the soft tissues.

Treatment procedures

In defects to be treated surgically buccal and lingual mucoperiosteal flaps were raised to expose the intraosseous lesion. Granulomatous tissue was removed and the osseous walls of the defect were uncovered. The root surfaces were carefully planed. Following bleeding control the root surfaces were treated by a 3-minute topical application of saturated citric acid (pH1) using cotton pledgets, followed by thorough irrigation with saline. Osseous recontouring was not performed. The flaps were replaced and sutured to obtain complete closure of the wounds.

Defects to be root planed were instrumented with curettes under local anesthesia. Intentional soft tissue curettage was not performed.

Chlorhexidine (Hibitane[®], ICI, Macclesfield, Great Britain) was prescribed for twice daily, 0.2% rinses to supplement the oral hygiene procedures during the first two postoperative weeks. Sutures were removed one week after surgery. The patients were seen at weekly intervals during the first three postoperative weeks and then again another three weeks later (six weeks postoperatively) for oral hygiene reinstruction and polishing of the teeth. Subsequently, the patients were seen every six weeks for oral hygiene reevaluation and tooth cleaning. No attempts at deep scaling or soft tissue curettage of the experimental sites were made at these appointments.

Statistical analyses

Analyses of variance were utilized to evaluate effect of treatment as observed by probing attachment and probing bone level changes and by the residual probing depth at 6 months. Various combinations of defect characteristics were used as covariates.

RESULTS

The pre- and postoperative records for the root planed and for the surgically treated defects are presented in Tables 1A and 1B and in Fig. 1. Analyses of variance demonstrated statistically significant differences between the two treatment modalities for all three parameters of healing. The treatment resulted in mean gain of probing attachment level of 0.8 mm in the root planed defects as compared to 1.3 mm for the surgically exposed and acid treated defects ($p < 0.05$). The probing bone level improved an average of 0.2 mm for the root planed areas as compared to 0.6 mm for the surgical group ($p < 0.01$). The mean preoperative probing pocket depth of 6.7 mm and 6.8 mm for the two groups were reduced to 5.2 mm and 4.1 mm respectively. The difference in residual probing depth between the two groups was statistically significant ($p < 0.001$).

Table 1 A. Pre- and postoperative records for the 25 root planed defects. Data for individual defects, means and standard deviations.

Sub- ject	Site	Preop probing pocket depth (mm)	Postop soft tissue crater depth (mm)	Postop full mouth plaque score %	Postop local site plaque score %	Postop full mouth bleeding score %
1	33 M	6.5	0	20.8	25	10.1
	41 M	5.75	0	20.8	25	10.1
	46 M	6.5	0	20.8	62.5	10.1
2	47 M	6	0	19.4	37.5	10
3	36 M	5.5	0.8	15.3	37.5	5.6
	47 M	6.25	0.5	15.3	25	5.6
4	13 D	6	0	9.6	0	11.9
	12 D	6.5	0.5	9.6	12.5	11.9
5	43 M	5.5	0	16.4	50	5
6	37 M	9	0.8	3.2	37.5	4.9
	25 D	6.25	1.5	3.2	12.5	4.9
7	12 M	6.75	0	5.7*	0*	23.4
	12 D	7.25	0	5.7*	16.7*	23.4
	23 M	7	0	5.7*	0*	23.4
8	23 M	9.75	0.3	19.4*	33.3*	21.5
9	35 M	5.75	0	19.1	62.5	15.3
	22 D	8.25	0	19.1	0	15.3
10	42 M	7	0.2	9.3	0	10
11	35 M	6.5	0	1	0	7.3
	35 D	6	0	1	0	7.3
12	45 D	6.5	0.5	8.5	0	8.3
	15 D	6	2.7	8.5	0	8.3
13	33 M	6.5	0	8.5	0	30.5
	33 D	7.5	0	8.5	0	30.5
14	43 M	7.5	1	7.6*	0*	9.5
Mean		6.7	0.4	11.7	17.5	12.4
S.D.		± 1.0	± 0.6	± 6.5	± 20.9	± 7.7

* Data based on recordings at 12, 18 and 24 weeks postoperatively.

Postop local site bleeding score %	Immediate postop probing depth (mm)	Immediate postop probing attachment change (mm)	Change of probing attachment level (mm)	Change of probing bone level (mm)	Residual probing depth (mm)
0	7.25	-0.75	0.5	0	5
16.7	6	-1	1.25	0.25	3.75
0	8.25	-1.5	-0.25	0	6.75
33.3	7.25	-1	1.75	0	3
33.3	7	-0.75	0.25	0.75	4.75
33.3	6	0.25	0	-0.5	5
0	6.5	-0.25	0.25	0.25	5.75
16.7	6.5	0	2.25	0.25	3.75
16.7	6.5	-1.75	0	-0.5	4.75
50	11.5	-1.5	1	0.5	7.5
16.7	6.75	-0.5	0.5	0	5.5
0	7	0	2.5	0	3.5
16.7	8	0	2	1.25	5.25
50	7.5	-0.25	0.5	0.5	6.25
0	7.25	-1.5	1.25	0.75	7.25
33.3	7.25	-0.5	0.75	0.75	4.25
0	8.5	-1	1.5	0.75	6
66.7	7	0	1	1	5
66.7	7.5	0	0.25	-0.25	5.5
50	6	0.25	1.5	0.5	3.5
33.3	7.75	-1	1.5	0.5	3.75
16.7	7.75	0	1.25	0	4.25
66.7	7.5	-1	-0.25	-1.75	5.75
83.3	8	-1	-0.75	-1	7
16.7	8	-0.25	0.25	0	6
28.7	7.4	-0.6	0.8	0.2	5.2
± 24.8	± 1.1	± 0.6	± 0.8	± 0.6	1.3

Table 1 B. Pre- and postoperative records for the 25 surgically exposed and acid treated defects. Data for individual defects, means and standard deviations.

Sub-ject	Site	Preop probing pocket depth (mm)	Number of tooth surfaces involved	Defect circumference (degrees)	Number of osseous walls of defect	Depth of 3+2+1-wall components of defect (mm)	Depth of 3+2-wall components of defect (mm)	Depth of 3-wall component of defect (mm)	Postop soft tissue crater depth (mm)
1	25 M	5.5	1	90	2	4	3	0.5	1.5
	22 D	5.5	2	120	3	3.5	1	0.75	1.3
2	13 D	6	1	90	3	3.25	3	2	1.7
	21 M	7.25	2	180	2	8.5	5	2	0.7
3	23 D	5.5	1	90	3	3.5	1	1	2.3
	25 M	5.5	1	90	3	3	3	2.25	0.5
4	36 M	6	1	90	3	5.5	2.25	1.5	0.3
	43 M	5.5	1	90	3	2.5	2.5	1.5	1.3
5	11 M	5.25	1	90	3	2.5	2	1.5	0.7
6	45 D	6.75	1	90	2	5.5	4.5	0.75	3
7	33 M	7	1	90	2	2	1	0.5	2.2
	34 M	7.5	1	90	3	3	1.75	1	1.2
	35 M	6.25	1	60	3	3.5	2.25	1	0
8	34 M	8.25	2	120	3	6.25	5	3	1.5
	35 M	9.75	3	210	3	7.25	6	3.5	1.3
9	43 M	6.25	1	90	3	3.5	3	1.5	1.7
10	22 M	7.75	1	90	3	4	2.5	2	0.7
11	45 M	6.5	3	270	2	4	3.25	3	2
	45 D	7	3	270	2	2.25	2	0	0.8
12	24 D	6	1	90	3	4	3	2.25	3
	25 D	7.5	1	90	3	5	4	2	3
13	35 M	8.5	2	270	2	5	3.75	1.5	0
	35 D	6.75	2	270	2	3	3	1	2.2
14	23 D	7.5	1	60	2	4	1.75	0	1.8
	25 M	7.5	2	180	3	3.5	2.5	2.5	1.5
Mean		6.8	1.5	130	2.6	4.1	2.9	1.5	1.4
S.D.		± 1.1	± 0.7	± 71	± 0.5	± 1.6	± 1.3	± 0.9	± 0.9

* Data based on recordings at 12, 18 and 24 weeks postoperatively.

Postop full mouth plaque score (%)	Postop local site plaque score (%)	Postop full mouth bleeding score (%)	Postop local site bleeding score (%)	Immediate postop probing depth (mm)	Immediate postop probing attachment change (mm)	Change of probing attachment level (mm)	Change of probing bone level (mm)	Residual probing depth (mm)
20.8	37.5	10.1	0	5.75	-1.5	-0.25	0.5	4.75
20.8	37.5	10.1	33.3	6.25	-1.75	0	0.75	4
19.4	25	10	16.7	6	-1.25	0.75	1.25	3.5
19.4	12.5	10	16.7	9.25	-3	2.75	1.25	4.25
15.3	37.5	5.6	0	5.5	-1.25	1.75	0.75	3.25
15.3	12.5	5.6	16.7	6.75	-1.5	1	0	3.5
9.6	50	11.9	33.3	5.75	-0.25	0	-0.25	5
9.6	25	11.9	50	4.75	-1	1	-0.25	3.75
16.4	0	5	33.3	6.25	-1.25	1.5	2	3
3.2	0	4.9	16.7	6.25	-0.5	1.75	1.75	3.25
5.7*	33.3*	23.4	50	5.75	-0.5	0.75	-0.25	3.75
5.7*	0*	23.4	16.7	4.75	-0.25	1.5	0.5	3.5
5.7*	33.3*	23.4	50	5.25	-0.75	1.5	0.25	3.75
19.4*	33.3*	21.5	16.7	7.5	-1.5	1	1	4.25
19.4*	16.7*	21.5	33.3	9.5	-0.75	2.75	3.25	4.75
19.1	37.5	15.3	66.7	6.25	-1.25	0.75	0.25	4.5
9.3	0	10	16.7	7.25	-1.25	2	2.25	3.75
1	0	7.3	16.7	6.5	-0.75	1.25	0	3.75
1	0	7.3	16.7	6.75	0	1.25	-0.5	4.75
8.5	12.5	8.3	16.7	6	-1.25	1.25	0.5	3.75
8.5	0	8.3	50	6.75	-0.75	1.75	0.5	4
8.5	50	30.5	66.7	8	-1	1.75	0.75	5.5
8.5	50	30.5	33.3	8	-1.75	0.25	0	4
7.6*	0*	9.5	0	7.75	-0.5	2	-0.25	4.75
7.6*	16.7*	9.5	33.3	7.25	-0.5	1.25	0	5.25
11.7	20.8	12.4	28.0	6.1	-1.0	1.3	0.6	4.1
± 6.5	± 18.1	± 7.7	± 19.1	± 1.2	± 0.6	± 0.8	± 0.9	± 0.7

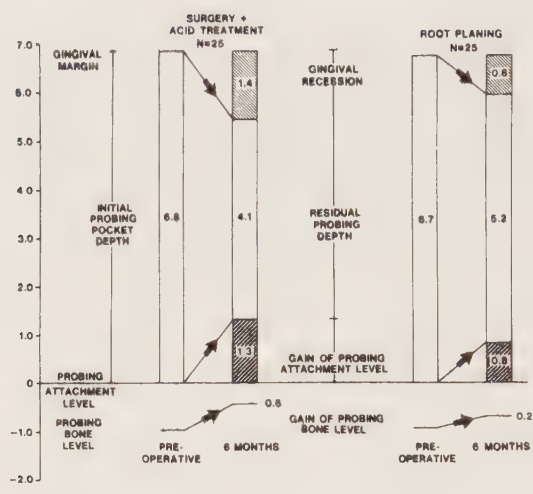


Fig.1. Schematic illustration of the mean effects of root planing and of surgical exposure with acid treatment. The figure shows what happened to the initial probing pocket depths in terms of the amounts of gingival recession, the amounts of gain of probing attachment level and the residual probing depth in mm. The pre- and postoperative probing bone levels relative to the probing attachment levels are also depicted.

DISCUSSION

The results of this study demonstrated an average gain of probing attachment amounting to 1.3 mm in the surgically treated areas as compared to 0.8 mm for the root planed areas. The limited gain of probing attachment level following surgical therapy and acid conditioning corresponds to the results of two of our previous studies (Chamberlain et al. 1984a, Renvert et al. 1984), but differs somewhat from the results of the first of our studies on treatment of intraosseous defects (Renvert & Egelberg 1981). This may be explained by the differences in design between this initial study and the following studies in our series of investigations. The use of a standardized probing force was introduced after the first study eliminating the possibility of inadvertently introducing a lighter probing force postoperatively, which may result in a higher magnitude of recorded probing attachment level gain (Proye et al. 1982, Chamberlain et al. 1984b). Also, the fact that the length of the period of initial preparation was only two months in the first investigation and that the defects were generally deeper than in the present study may be of importance.

The mean gain of probing bone level was 0.6 mm following the surgical therapy and 0.2 mm following root planing. The limited bone fill after the surgical therapy is at variance with the bone apposition reported by Rosling et al. (1976) and Polson & Heijl (1978), but more in agreement with the findings by Froum et al. (1982), Chamberlain et al. (1984a) and Renvert et al. (1984). The absence of bone fill following root planing is probably explained by the nature of this procedure. Root planing will leave most of the chronic inflammatory tissue behind the defect and will not remove the connective tissue adjacent to the osseous walls. These remaining tissues may prevent or retard bone apposition which may be facilitated by a surgical denudation followed by formation of a coagulum next to the defect walls.

The results of the present study are somewhat contradictory to the findings by Isidor (1981), who observed a tendency towards more gain of probing attachment level following root planing alone compared to full coverage flap surgery. There seems to be no apparent explanation to these differences in results. However, the differences between root planing

alone and surgery in the study by Isidor (1981) are small and not statistically significant. Also, the mean gains of probing attachment level in both studies are limited and within the 0.5-1.5 mm range.

Postoperative soft tissue craters were only occasionally observed following root planing, whereas this feature occurred frequently following the surgical procedures in this study as well as in one of our previous studies (Renvert et al. 1984). Inadequate surgical technique with incomplete closure of the interdental wound would seem to be a likely explanation to the development of these craters. However, the fact that soft tissue craters have developed following surgical procedures carried out by three different operators participating in our studies may indicate that craters may occur in spite of careful attempts at wound closure.

The present study together with our previous investigations (Renvert & Egelberg 1981, Chamberlain et al. 1984a, Renvert et al. 1984) demonstrate that short term clinical improvements can be accomplished following treatment of intraosseous periodontal defects using a variety of treatment modalities. The magnitude of these improvements has been limited in our studies, including the improvements following regenerative attempts using citric acid root conditioning and osseous grafting. In fact, the similarity of results following root planing alone may question the justification of surgical procedures. However, at this point our studies have been limited to 6 and 12 months of observation. It is possible that the greater amount of pocket reduction obtained following surgical procedures may be of long term significance. The pocket reduction can be further enhanced by recontouring of the osseous walls without apparent compromise of the probing attachment gain (Chamberlain et al. 1984a). A shallower residual probing depth may be more resistant to subgingival recolonization of microorganisms and subsequent reoccurrence of disease than areas with deeper residual probing depths.

The limited overall amount of regeneration observed in our studies seems to imply that clinically significant regeneration cannot be anticipated in the "average" osseous defect. Regeneration of osseous defects does not seem to be predictable. However, there are numerous case reports in the literature demonstrating that marked regeneration can occur (i.e.

Prichard 1957, Patur & Glickman 1962, Dragoo & Sullivan 1973, Hiatt et al. 1978, Bowers et al. 1982). Future studies should be performed aiming at identification of the specific circumstances that exist when clinically significant regeneration of intraosseous defects occur.

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Paper VI

HEALING AFTER TREATMENT OF PERIODONTAL
INTRAOSSEOUS DEFECTS

VI. Factors influencing the healing response

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Running head: Healing of intraosseous defects

Key words: Periodontal healing - osseous defects -
regeneration

ABSTRACT

84 periodontal intraosseous defects treated with mucoperiosteal replaced flap surgery and citric acid root conditioning were used to study the relationships between various defect characteristics and the healing response as expressed by change of probing attachment level, change of probing bone level and residual probing depth. More gains in probing attachment and probing bone levels were observed in deep defects than in shallower lesions. Other defect characteristics showed weak or no correlations to defect fill. The findings of this study seem to indicate that the outcome of treatment of intraosseous defects may be difficult to predict based upon evaluation of defect characteristics.

INTRODUCTION

The bone morphology of periodontal intraosseous lesions has been considered of importance to the potential of obtaining regeneration following therapy. Enhanced regeneration has been observed as the number of osseous walls circumscribing the defects increases. 3-wall defects seem to show the most favorable response to treatment and 2-wall defects seem to have greater healing potential than 1-wall defects (Patur & Glickman 1962, Ellegaard & L   1971, Carraro et al. 1976, Quintero et al. 1982). Other studies have shown similar regeneration of 2-wall and 3-wall defects (Rosling et al. 1976a,b, Polson & Heijl 1978).

Froum et al. (1975) suggested that the total amount of osseous tissue surrounding the defect, or the depth of the osseous defect, rather than the number of osseous walls may determine the amount of bone apposition in the lesions following therapy.

The number of root surfaces involved by the osseous defect has also been considered to influence the healing response. Defects located at one surface only are thought to have a greater potential for regeneration than defects encompassing two or three surfaces (Schaffer 1958, Wade 1966, Prichard 1972). However, Polson & Heijl (1978) did not observe any difference in osseous fill between defects located at one or more root surfaces.

In the present study factors influencing the healing response following treatment of intraosseous lesions have been further investigated.

MATERIAL AND METHODS

Subjects

84 periodontal intraosseous defects in 51 patients, aged 23 to 72, were used for the study. The defects were part of the material of four previous studies (Renvert & Egelberg 1981, Chamberlain et al. 1984, Renvert et al. 1984a,b). Only defects treated with the same surgical procedure (replaced flap and citric acid root conditioning); recorded with the same clinical parameters; and having complete data for all investigated parameters were included in the present report. The fundus of all defects was located at proximal tooth surfaces. Defects adjacent to teeth with root furrows, root concavities or furcation apertures were not included. 13 defects were present in incisors, 14 in cuspids, 40 in bicuspid and 17 in molars.

Initial therapy of oral hygiene instruction and root planing was performed a minimum of two months prior to final patient and site selection. Only sites with probing pocket depth $\geq$ 6 mm at reevaluation were included.

Parameters

The following recorded parameters were analyzed:

- 1) probing pocket depth
- 2) probing attachment level
- 3) probing bone level
- 4) number of tooth surfaces involved
- 5) osseous defect circumference
- 6) number of osseous walls of the defect
- 7) depth of 3+2+1-, 3+2- and 3-wall components of the defect.

Probing pocket depths, probing attachment levels and probing bone levels were measured preoperatively and 6 months postoperatively. The osseous defect characteristics were recorded during the surgical procedures.

Probing pocket depth and probing attachment level: Measurements of probing pocket depth and probing attachment level were made using an electronic pressure sensitive probe (Electronic Periodontal Probe, Model 200, Vine Valley Research, Middlesex, N.Y., U.S.A.). A specially machined probe tip with 1 mm increments and 0.5 mm diameter was used. Each site was probed using a standardized force of 0.75 N. Recordings to the nearest 0.5 mm were made from the buccal and lingual aspects of the proximal defect sites. A vacuum-adapted soft acrylic onlay (Scheu-Dental, Iserlohn, West Germany) was used to provide reference points for the probing measurements (Froum et al. 1975, Badersten et al. 1984c). The placement of the probe was guided by the interdental indentations of the thin onlay and the probe was directed apically toward the deepest point on the mid-proximal aspect of the root surface. Probing pocket depth was measured from the gingival margin to the tip of the probe. Probing attachment level was recorded from the onlay margin to the tip of the probe. Means of the buccal and lingual recordings for each proximal defect were used to evaluate the effect of treatment.

Probing bone level: Immediately after probing pocket depth and probing attachment level measurements were completed, probing bone level measurements were taken under local anesthesia using a similar probe tip. During probing, the probe was directed apically toward the mid-proximal aspect of the root surface and forced through the soft tissue toward the bone until definite resistance was met. The probing bone level was recorded as the distance from the onlay margin to the probe tip. Means of buccal and lingual recordings were calculated.

Osseous defect circumference, number of tooth surfaces involved and number of osseous walls of the defect: These characteristics were recorded after debridement of the surgical sites. The circumference of the osseous defect in relation to the root circumference was estimated to the nearest 30° at the coronal portion of the defect. The number of tooth surfaces involved was recorded as 1 if the defect was localized to the proximal tooth surface only, as 2 when the defect also encompassed the buccal or lingual surface, and as 3 when proximal, buccal and lingual surfaces were involved. The number of osseous walls of the defects was recorded as 1 when only a proximal wall was present, as 2 if the proximal defect had a buccal or lingual wall, and as 3 when both buccal and lingual walls were present.

Depth of 3+2+1-, 3+2- and 3-wall components of the osseous defect: The osseous defect depth was recorded using the onlay margins as reference points for a series of measurements. The distance to the most apical extent of the proximal defect was measured from both buccal and lingual onlay margins. The crest of the buccal wall of the defect was measured from the buccal onlay margin. The crest of the lingual wall of the defect was measured from the lingual onlay margin. The crest of the proximal wall of the defect was measured from both buccal and lingual onlay margins.

The height of the buccal wall was calculated by subtracting its crest level measurement from the buccal measurement of the apical extent of the osseous defect. Similarly, the lingual wall height was calculated from the corresponding lingual measurements. To calculate the height of the proximal wall, the average of the buccal and lingual measurements of its crest was subtracted from the average of the buccal and lingual measurements of the apical extent of the defect. In this way the depths of the defect could be expressed relative to the number of walls of the defect. Consequently, the depths were calculated for the 3-wall, 3+2-wall and the 3+2+1-wall components of the defects. The figures give only approximate representation of the defect components due to the fact that angulation of the probe had to be varied to obtain the different measurements.

Consistency of recordings: In spite of the fact that the defects for this report were retrieved from four different studies, there was a general uniformity of the recordings. There were some exceptions to the uniformity:

- 1) All measurements were made by one examiner (author S.R.) except for the recordings in 13 defects, which were performed by a second examiner (author A.D.H; Chamberlain et al. 1984).
- 2) All probing pocket and probing attachment level measurements were made using a pressure sensitive probe and 0.75 N probing force except in 22 defects, where a standardized probing force was not used for the pre- and postoperative recordings (Renvert & Egelberg 1981).

- 3) The number of osseous walls in 13 defects was enumerated according to the dominant clinical morphology of the defect and was not counted according to their presence as described above (Chamberlain et al. 1984).
- 4) Postoperative measurements were made after 6 months except for 25 defects, which were recorded after 12 months (Renvert et al. 1984a).

Treatment procedures

Buccal and lingual mucoperiosteal flaps were raised. Granulomatous tissue was removed and the osseous walls of the defect were uncovered. The root surface was planed and treated by a 3-minute topical application of saturated citric acid using cotton pledgets, followed by thorough irrigation with saline or water. Osseous recontouring was not performed. The flaps were sutured to obtain complete closure of the wounds.

Chlorhexidine (Hibitane[®], ICI, Macclesfield, Great Britain) was prescribed for twice daily, 0.2% rinses to supplement the oral hygiene procedures during the first two postoperative weeks. Sutures were removed one week after surgery. The patients were seen at weekly intervals during the first postoperative weeks and then six weeks postoperatively for oral hygiene evaluation, reinstruction and polishing of the teeth. Subsequently, the patients were seen every six weeks for oral hygiene reevaluation and rubber cup polishing of the teeth. No attempts at deep scaling or soft tissue curettage of the experimental sites were made at these appointments.

Statistical analyses

The relationship between defect characteristics and the parameters of healing was determined using multiple regression analyses. Using probing attachment level change, probing bone level change and residual probing depth as the independent variable and compensating for patient variability, partial coefficients of correlation were calculated for the various defect characteristics.

A series of additional multiple regression analyses were made to evaluate the importance of the inconsistencies of the recordings listed above. For

each of these, separate analyses were performed in which the defects with the particular recording deviation were excluded from analysis. The magnitudes of the coefficients of correlation in these analyses were compared to the corresponding coefficients from the analyses of all 84 defects.

Separate analyses of regression were also performed to study the influence of age of the patient and the influence of tooth groups (incisors, cuspids, bicuspid and molars) on the parameters of healing.

RESULTS

The characteristics of the defects under investigation are presented in Table 1 and demonstrate a wide range in depth and morphology. The changes following therapy are presented in Tables, 2 and 3. A mean gain of probing attachment level amounting to 1.4 mm and a mean gain of probing bone level of 1.0 mm was observed. The initial mean probing pocket depth was reduced from 7.0 mm to 4.4 mm.

Table 1. Characteristics of the 84 intraosseous periodontal defects under investigation. Means, standard deviations and ranges.

Defect characteristic	Mean $\pm$ S.D.	Range
Preoperative probing pocket depth (mm)	7.0 $\pm$ 1.6	4.50 - 11.25
Number of tooth surfaces involved	1.7 $\pm$ 0.8	1 - 4
Defect circumference (degrees)	131 $\pm$ 69	60 - 360
Number of osseous walls of defect	2.6 $\pm$ 0.6	1 - 3
Depth of 3+2+1-wall component (mm)	4.6 $\pm$ 1.9	1.75 - 9.00
Depth of 3+2-wall component (mm)	3.5 $\pm$ 1.9	1.00 - 9.00
Depth of 3-wall component (mm)	2.0 $\pm$ 1.5	0.00 - 7.00

Table 2. Change of probing attachment level, probing bone level and residual probing depth following treatment of the 84 intraosseous periodontal defects under investigation. Means, standard deviations and ranges.

	Mean $\pm$ S.D.	Range
Change of probing attachment level (mm)	1.4 $\pm$ 1.0	-1.25 - 4.50
Change of probing bone level (mm)	1.0 $\pm$ 1.1	-1.25 - 4.00
Residual probing depth (mm)	4.4 $\pm$ 1.3	2.00 - 9.75

Table 3. Number and percentage of defects demonstrating different magnitude of change of probing attachment level and probing bone level.

Magnitude of change (mm)	Change of probing attachment level	Change of probing bone level
-1.25 - -2.00	1 (1%)	1 (1%)
-0.25 - -1.00	3 (4%)	12 (14%)
0.00 - 0.75	22 (26%)	30 (36%)
1.00 - 1.75	28 (33%)	18 (21%)
2.00 - 2.75	25 (30%)	16 (19%)
3.00 - 3.75	3 (4%)	6 (7%)
4.00 - 4.75	2 (2%)	1 (1%)
Total	84 (100%)	84 (100%)

The coefficients of correlation between various defect characteristics and the parameters of healing are presented in Table 4. The change of probing attachment level was significantly correlated to the preoperative probing pocket depth ($r=0.47$, $p < 0.01$) and to the depth of 3+2+1-wall component of the osseous defect ($r=0.36$, $p < 0.05$). The change of probing bone level was significantly correlated to the depths of the 3+2+1- and the 3+2-wall components of the defects ($r=0.44$, $p < 0.01$ and $r=0.36$, $p < 0.05$ respectively). The residual probing depth showed significant correlations to preoperative probing pocket depth, number of tooth surfaces involved and defect circumference ($r=0.50$, $p < 0.01$; $r=0.50$, $p < 0.01$ and $r=0.58$, $p < 0.001$ respectively). The above coefficients of correlation were little affected by the step-wise exclusions from analyses of defects with deviations of recording uniformity.

Table 4. Coefficients of correlation between various defect characteristics for the total material of 84 defects and the healing response as evidenced by change of probing attachment level, change of probing bone level and residual probing depth.

Defect characteristic	Coefficient of Correlation		
	Change of probing attachment level (mm)	Change of probing bone level (mm)	Residual probing depth (mm)
Preoperative probing pocket depth (mm)	0.47**	0.22	0.50**
Number of tooth surfaces involved	-0.11	-0.02	0.50**
Defect circumference (degrees)	-0.15	-0.14	0.58***
Number of osseous walls of defect	-0.02	0.28	-0.33
Depth of 3+2+1-wall component (mm)	0.36*	0.44**	0.13
Depth of 3+2-wall component (mm)	0.22	0.36*	0.27
Depth of 3-wall component (mm)	0.09	0.07	0.28

*: $p < 0.05$; **: $p < 0.01$; ***: $p < 0.001$.

Subsamples of the total material of 84 defects are presented in Tables 5 and 6. Table 5 presents defect characteristics for 30 sites which showed 2 mm or more gain of probing attachment level as opposed to the characteristics of 13 sites demonstrating no change or loss of probing attachment level. Table 6 presents defect characteristics for 23 sites which showed 2 mm or more gain of probing bone level as opposed to 22 sites demonstrating no change or loss of probing bone levels. The tables reveal limited differences in defect characteristics between these polarized best responding and non-responding sets of defects.

Insignificant relationships were found in the analyses of regression performed to study the influence of age of the patient and the influence of location of defects by tooth groups.

Table 5. Characteristics of sites showing 2 mm or more gain of probing attachment level and sites demonstrating no change or loss of probing attachment level.

Defect characteristic	Change of probing attachment level	
	≥ 2.0 mm (N=30) ($\bar{X}$: 2.4 ± 0.6 mm)	≤ 0.0 mm (N=13) ($\bar{X}$: -0.2 ± 0.4 mm)
Preoperative probing pocket depth (mm)	7.7 ± 1.9	6.7 ± 1.7
Number of tooth surfaces involved	1.9 ± 0.9	2.1 ± 1.0
Defect circumference (degrees)	137 ± 63	173 ± 98
Number of osseous walls of defect	2.5 ± 0.7	2.5 ± 0.7
Depth of 3+2+1-wall component (mm)	5.1 ± 2.2	4.9 ± 1.7
Depth of 3+2-wall component (mm)	4.0 ± 2.4	3.6 ± 1.9
Depth of 3-wall component (mm)	2.2 ± 1.9	2.1 ± 1.3

Table 6. Characteristics of sites showing 2 mm or more gain of probing bone level and sites demonstrating no change or loss of probing bone level.

Defect characteristic	Change of probing bone level	
	> 2.0 mm ($\bar{N}=23$) ($\bar{X}$: 2.5 ± 0.6 mm)	< 0.0 mm ($\bar{N}=22$) ($\bar{X}$: -0.3 ± 0.3 mm)
Preoperative probing pocket depth (mm)	7.8 ± 2.1	6.7 ± 1.3
Number of tooth surfaces involved	2.0 ± 0.9	1.8 ± 0.9
Defect circumference (degrees)	134 ± 65	153 ± 91
Number of osseous walls of defect	2.4 ± 0.7	2.5 ± 0.6
Depth of 3+2+1-wall component (mm)	5.6 ± 2.2	4.0 ± 1.8
Depth of 3+2-wall component (mm)	4.8 ± 2.3	3.0 ± 1.7
Depth of 3-wall component (mm)	2.8 ± 2.0	1.9 ± 1.3

DISCUSSION

All of the intraosseous defects of the present study were subjected to a full coverage flap procedure with citric acid conditioning of the root surfaces. The findings of the relationship between defect characteristics and parameters of healing, therefore, apply to acid treated defects only. However, there are no apparent reasons to believe that the relationships would be notably different for non-acid treated defects.

The overall effect of the regenerative therapy in terms of mean gain of probing attachment level and mean gain of probing bone level was limited. The gains were smaller than what has been reported in several

investigations (i.e. Carraro et al. 1976, Rosling et al. 1976a,b, Polson & Heijl 1978) but comparable to the results of other studies (i.e. Altieri et al. 1979, Pearson et al. 1981, Rabalais et al. 1981, Froum et al. 1982). The possible explanations for these differences have been discussed in our previous papers (Chamberlain et al. 1984, Renvert et al. 1984a,b). In spite of the overall limited healing response, the results varied substantially in the 84 defects under study and the material was considered adequate for the present analysis of relationships between healing response and defect characteristics.

To some extent there was a lack of uniformity of the recordings of the defects under study. In the series of analyses performed in order to evaluate the importance of these inconsistencies it was found that the coefficients of correlation remained similar. Thus, it could be established that neither the lack of uniformity of recordings nor the difference in observation interval affected the relationships or the lack of relationships that were observed.

The change of probing attachment level was significantly related to the peroperative probing pocket depth and to the total depth of the osseous defect. The relationship to preoperative pocket depth is in agreement with several studies on the effect of non-surgical and surgical periodontal therapy (Knowles et al. 1979, Hill et al. 1981, Pihlstrom et al. 1981, Lindhe et al. 1982a,b, Badersten et al. 1984a,b).

The change of probing bone level was significantly related to the depths of the 3+2+1-wall and 3+2-wall components of the defects. The number of osseous walls of the defects, the defect circumference and the number of tooth surfaces involved showed little or no relationship with bone fill. These lacks of relationships are contradictory to several previous observations (Schaffer 1958, Patur & Glickman 1962, Wade 1966, Ellegaard & Löe 1971, Prichard 1972, Carraro et al. 1976, Quintero et al. 1982) but in agreement with the suggestion by Froum et al. (1975) and the findings by Polson & Heijl (1978). In the present investigation and in the study by Polson & Heijl (1978) more systematic and objective recordings of the defect characteristics were used. This approach is desirable from a scientific point of view during attempts to analyze the current relationships. However, a subjective evaluation of the overall defect type which

may include the examiners' bias of the expected healing response may have its merit and may explain why several studies have observed a positive relationship between bone fill and number of osseous walls and a negative relationship to the number of tooth surfaces involved.

In spite of the fact that some defect characteristics showed statistically significant relationships to the parameters of healing, the coefficients of correlation were generally low. The limited influence of the various defect characteristics is also evident from Tables 5 and 6. A comparison of the best responding defects (2.0 mm or more gain of probing attachment or probing bone level) with the non-responding defects (no change or loss) revealed limited differences between these polarized groups. Thus, the findings of this study seem to indicate that the outcome of treatment of intraosseous defects may be difficult to predict based upon evaluation of defect characteristics.

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